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ALUM SLUDGE TREATMENT AND DISPOSAL

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Alberta ENVIRONMENT

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ALUM SLUDGE TREATMENT AND DISPOSAL

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MARCH, 1984

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Alberta Environment
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9820 - 106 Street
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Attention: Mr. David Spink, M.Sc., P.Eng.
Branch Head, Municipal Engineering

Dear Sirs:

RE: ALUM SLUDGE TREATMENT AND DISPOSAL

We are pleased to submit herewith our final report on the above noted subject.

The report reviews the characteristics, treatment and disposal methods for alum sludges generated by water treatment plants. It is concluded that alum sludges exhibit a wide range of characteristics and, in some cases, may have deleterious effects if discharged directly to receiving waters. To mitigate these effects, there are several options which may be considered for the treatment and disposal of alum sludges in Alberta.

It is recommended that baseline data aquisition, bioassay testing and other studies should be initiated to confirm the magnitude of direct stream disposal practices in Alberta, and to assess alternate disposal methods.

We would like to thank you for the opportunity to undertake this study and trust that the report meets your expectations.

Yours truly,

UNDERWOOD McLELLAN LTD.

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1.0 EXECUTIVE SUMMARY

Treatment and disposal methods for alum sludges from water treatment plants (WTPs) are examined in this report. In Alberta, the most common practice has been to discharge these sludges directly back to a river or stream. Alberta Environment is currently reviewing this practice to determine if it should be continued, or if alternate disposal methods should be considered.

Alum is the most commonly used chemical in the treatment of Alberta surface waters for turbidity and/or colour removal. Alum is usually one of the first chemicals added to the raw water, where it is rapidly mixed, followed by slow mixing to promote the formation of floc particles. These particles contain sediment and colloidal substances removed from the water and aluminum hydroxide, which is produced in the reaction of alum and water. The majority of the floc is removed from the water by sedimentation. The settled floc (alum sludge) requires either periodic or continuous removal to maintain sedimentation process efficiency.

This report may be considered as a starting point for Alberta Environment's review of alum sludge disposal methods. The report is based largely on an analysis of readily available information from published literature and other sources covering several subject areas, including the following:

- analysis of data on alum sludge, including environmental effects;
- alum sludge treatment and disposal options;
- options applicable in Alberta; and
- regulatory requirements in Canada and the USA.

Conclusions

Conclusions arising from this review are summarized as follows:

1. The present practice of disposing alum sludge to receiving streams in Alberta may or may not be environmentally acceptable. Further assessment of the practice is required to determine if the practice should continue to be allowed.

2. There appears to be a lack of good scientific evidence of problems from disposing alum sludge to receiving streams. There have been numerous suspicions expressed about adverse effects, but these often have not been substantiated by factual information.

3. Possible adverse effects of alum sludge discharges include:

   - formation of sludge deposits in quiescent areas of streams;
   - smothering effects on benthic organisms;
   - toxic effects on aquatic organisms (high toxicity has been reported in bioassay tests);
   - periodic high oxygen demand if WTP sludge is discharged in large slugs, or if previously deposited sludge is periodically re-suspended due to increased stream velocity;
   - increase in aluminum concentrations of downstream water supplies; and
   - aesthetic problem where stream flow, stream turbidity, and/or sludge dilution are low.

4. Alum sludge is gelatinous and difficult to handle and dewater. Its gelatinous nature and poor dewaterability generally increase with raw water colour and decrease with raw water turbidity.

5. The minimum solids concentration of dewatered alum sludge preferred for landfilling, when the sludge is mixed with refuse, is about 20% total solids (TS) by weight. This gives the sludge the appearance of soft clay. However, much more dilute sludges have been landfilled, causing some difficulties because of the creation of muddy conditions. At about 40% TS, the sludge resembles stiff clay. As such, it does not require mixing with refuse and can be landfilled separately, or possibly used as a cover material.

6. Alum sludge exhibits a wide range of characteristics which depend on the raw water characteristics (turbidity, etc.) and other factors. Parameters may range as follows:

Total Solids:	0.1 - 4%
Suspended Solids:	75 - 99% of TS
Volatile Solids:	10 - 35% of TS
Biochemical Oxygen Demand:	30 - 2,000 mg/L
Chemical Oxygen Demand:	500 - 20,000 mg/L
pH:	5.5 - 7.5
Aluminum:	4 - 11% of TS
Iron:	6.5% of TS (one sample)
Manganese:	<0.005 - 5% of TS

Arsenic:	<0.04% of TS
Cadmium:	<0.005% of TS
Individual Heavy Metals:	<0.03% of TS
Total Kjeldahl Nitrogen:	0.7 - 1,200 mg/L as N
Phosphate:	0.3 - 200 mg/L as P
Total Plate Count:	30 - >300,000 per mL

7. The following appear to be viable options for handling, treatment and disposal of alum sludge:

   - discharge to receiving stream;
   - reduce alum sludge quantities by substituting some polymer for alum;
   - discharge at controlled rates to a sanitary sewer;
   - lagooning, with natural freeze-thaw dewatering;
   - thickening and dewatering followed by landfilling; and
   - land application.

   Another option involves the elimination of alum sludge through the use of alternate coagulants.

8. When dewatered alum sludge is disposed in a landfill, segregated disposal may have merit. It is estimated that as much as 500 tonnes of aluminum as Al with an estimated value exceeding $1 million, could be deposited in a segregated landfill area each year for a city of 500,000 people. The technology to re-mine this aluminum deposit economically may not be available today, but possibly could be developed in future.

9. Alum recovery by acidulation and re-use at a water treatment plant may not be a viable option because of concerns with respect to heavy metal and organics recycling.

10. Re-use of recovered alum at a wastewater treatment plant for phosphorus removal appears promising.

11. Alum recovery by liquid ion exchange has not been demonstrated at full scale. The process may not be suitable because of the apparent high complexity of operation and possibility of alum contamination with solvent. These aspects were not addressed in any of the reviewed references.

12. Land application of alum sludge at controlled rates can have beneficial effects on soils, for example: decreased slaking and dispersion, improved soil aggregation, increased water retention, and increased crop yield.

13. The costs of full scale alum sludge dewatering systems can be very expensive in terms of both capital and operation and maintenance (O & M). Capital costs may represent over 30% of water treatment plant capital costs. O & M costs may be in the order of $100 per tonne of dewatered solids.

14. It appears that two Canadian Provinces (Ontario and Saskatchewan) and the majority of USA states prohibit direct discharge of WTP alum sludge to streams.

Recommendations

The following are recommendations for consideration by Alberta Environment:

1. Alberta Environment should initiate baseline data acquisition on alum sludge discharges to determine the magnitude of the practice in Alberta. Data should include:

   - physical and chemical characteristics of alum sludge;
   - disposal method;
   - quantity disposed to receiving water;
   - discharge rates, duration, frequency, timing, etc.;
   - minimum dilution; and
   - impacts on receiving waters (in terms of calculated increases of parameters above background levels).

2. Bioassay testing should be undertaken on selected alum sludges. Initially, limited testing should be performed on sludges where there appear to be potential disposal problems. Ultimately, the testing could be extended to include sludges producing the greatest calculated increases of water quality parameters above background stream levels as identified in (1).

3. Laboratory, pilot scale, or other experimental studies of alum sludge treatment and disposal should be conducted for specific plants having potential adverse impacts, as identified in (1) and (2). Methods which appear worthy of examination initially include:

   - disposal to sanitary sewer with evaluation of impacts on sewer system and wastewater treatment processes including lagoons;

- natural freeze-thaw conditioning and dewatering:
    - with annual removal of dewatered, dried solids for landfill disposal,
    - with successive annual applications, in-place accumulation of freeze-thawed sludge, and ultimate land re-use or mining of the dried sludge to recover aluminum;
- alum recovery by acidulation with re-use of the recovered alum for phosphorus removal at wastewater treatment facilities.

4. Alberta Environment should develop guidelines with respect to alum sludge disposal in Alberta. Interim guidelines may be formulated, based on the findings of this study. The guidelines should be revised, as required, and finalized upon completion of the work outlined in (1) - (3).

5. If alum sludge dewatering is practised, the feasibility and merits of sludge disposal in segregated areas of a landfill should be investigated. With segregated disposal, ultimately it might be feasible to re-mine the deposited sludge to recover aluminum or alum.

6. The feasibility of land application of WTP alum sludge should be investigated further. Contacts with Ontario Ministry of the Environment and the New Haven Agricultural Experimental Station, in Conneticut are suggested starting points in the investigation.

2.0 INTRODUCTION

In this report, treatment and disposal methods for alum sludges from water treatment plants (WTPs) are examined. Alum sludges are produced when alum [aluminum sulphate or $Al_2(SO_4)_3 \cdot 14H_2O$] is used for coagulation and flocculation of raw water supplies to remove turbidity and/or colour. The floc particles are removed mainly during the sedimentation process in which the flocs slowly settle and form a sludge blanket. This blanket is referred to as alum sludge and consists of aluminum hydroxide ($Al(OH)_3$) and other particles and flocculated materials.

To maintain adequate efficiency of sedimentation basins, the alum sludge requires periodic or continuous removal. In Alberta, the most common practice is to discharge alum sludges from water treatment plants directly back to a river or stream. Alberta Environment is currently reviewing this practice to determine if it is acceptable, or if alternate disposal methods should be considered. This report is intended to provide assistance to Alberta Environment in their review of WTP alum sludge disposal.

Alberta Environment's (1982) water and wastewater facilities survey lists approximately 80 water treatment plants in Alberta with sedimentation facilities. The number of plants using alum, and producing alum sludge, was not indicated; however, it is likely that the majority of these plants use alum at least for a portion of the time each year. Information on the number of these plants discharging alum sludge directly to receiving water was not readily available, and data on the quantity of sludge discharged is generally not recorded. Therefore, the magnitude of the practice is not known at this time.

The detailed Terms of Reference for this study are included in Appendix A. In summary, the Terms of Reference required the preparation of a report which outlines:

1. quantities of alum sludge as a function of raw water characteristics;
2. alum sludge characteristics;
3. sludge dewatering characteristics;
4. sludge dewatering methods and costs;
5. alum recovery methods and costs;
6. ultimate disposal methods and costs;
7. possible physical, chemical and biological effects of disposing of water-treatment-plant alum sludges into surface waters;
8. applicability of various methods in Alberta;
9. regulatory requirements; and
10. description of relevant alum sludge treatment, recovery and disposal operations, including costs.

3.0 ALUM SLUDGE DATA ANALYSIS

This section reviews data on alum sludge from water treatment plants and investigates reasons why this waste product should, or should not, be discharged directly back to a receiving stream. Most of the information presented is based on a review of literature on the subject.

3.1 ALUM SLUDGE CHARACTERISTICS

Extensive information is available on the characteristics of alum sludge, although only a limited amount of this information was readily available for Alberta water treatment plants.

Alum sludge from settling tanks or clarifiers of water treatment plants is generally described as thixotropic and gelatinous. This is descriptive of alum sludge's poor dewatering characteristics.

Information on alum sludge characteristics is summarized in Appendix B (Tables B-1, B-2 and B-3). The Table B-1 data are based on a fairly extensive literature review. Tables B-2 and B-3 summarize information from Ontario water treatment plants reported by Hutchison et al. (1973).

A review of the tabulated data indicates the following approximate characteristics for alum sludge.

1. Total Solids Concentration
    - wide range: 0.1 to 27% by weight
    - typical range: 0.1 to 4%

- factors affecting concentration:
  - raw water sediment
  - use of polymers
  - type of basin: sedimentation tank or clarifier*
  - method of cleaning basin (manual or mechanical)
  - time interval between basin cleanings
  - type of mechanical basin cleaning equipment
  - method of sampling (in-place or discharge, before or after draining or decanting, with or without flushing water, etc.)

2. Volatile Solids
   - typical range: 10 to 35% of total solids

3. Suspended Solids
   - typical range: 75 to 99% of total solids

4. pH
   - typical range: 5.5 to 7.5

5. BOD
   - typical range: 30 to 2,000 mg/L
   - maximum reported: 6,000 mg/L

6. COD
   - typical range: 500 to 20,000 mg/L
   - maximum reported: 27,000 mg/L

---

* In this report, a sedimentation tank is considered to be a cross-flow settling tank, whereas a clarifier is an upflow or solids contact unit.

7. Aluminum (limited data)
   - range: 4 to 11% of TS as Al
   - % Aluminum appears to be greater for lower turbidity raw water

8. Iron
   - 6.5% of TS (one sample)

9. Manganese
   - range: <0.005 - 5% of TS

10. Arsenic
   - <0.04% of TS

11. Cadimum
   - <0.005% of TS

12. Individual Heavy Metals
   - <0.03% of TS

13. Total Kjeldahl Nitrogen
   - range: 0.7 to 1,200 mg/L as N

14. Phosphate
   - range: 0.3 to 300 mg/L as P

15. Total Plate Count
   - range: 30 - >300,000 per mL

3.2 ENVIRONMENTAL EFFECTS

Much of the material in water treatment plant sludge consists of the solids that were originally present in the raw water. However, these solids have been concentrated many times and, as such, may be considered as pollutants. Slug discharges of the sludge may magnify this pollution even further.

The direct discharge of water treatment plant alum sludge to streams may lead to a number of potential problems:

- formation of sludge deposits in quiescent areas or localized areas around the discharge location;
- adverse effects on benthic organisms due to smothering effect of settled sludge and toxicity of aluminum;
- stress on the stream's oxygen resources when oxygen demand of the sludge is high (Bugg etal., 1970) and/or prolonged, or when stream re-aeration is negligible (e.g. ice-covered river);
- potential problems if sludge blanket is flushed away by short period storms causing a downstream shock loading to the stream (Guiver, 1972; Gates, 1981); and
- organic material from sludge may be a potential source of taste and odours for downstream water users and a potential nutrient source for undesirable biological growths (Guiver, 1972).

Environmental effects will be a function of the following:

- characteristics of alum sludge;
- nature of receiving water and aquatic habitat; and
- dispersion and dilution of the sludge in the receiving water.

Since there are numerous combinations of conditions which can occur, the question of environmental effects is difficult to answer. Individual studies of each situation are necessary to attempt to define each case's environmental acceptability.

The impact of alum sludge disposal in landfills may have a greater potential impact than in streams (Gates, 1981, quoting an unreferenced AWWA publication). Landfills are predominantly anaerobic systems with acid forming bacteria. Any leachate produced may have an acidic pH, particularly if it is not well buffered. At low pH, there may be a tendency to redissolve some of the heavy metals contained in the sludge.

Specific cases in which environmental effects or aesthetic problems were described in the literature are presented in the remainder of this section.

Mahoney and Duensing (1972) reported on public complaints regarding alum sludge discharge at Albany, N.Y. The complaints first were voiced by downstream property owners in 1934 and continued into 1942. The complaints were then avoided by discharging sludge only at nights and during periods of high stream flow. It was not until 1965 that regulatory authorities requested the cessation of alum sludge discharges into New York's surface waters.

Nielsen (1977) reported on aesthetic problems associated with alum sludge discharge from the Sabronte Water Treatment Plant in the San Fransisco Bay area. Plant wastes were discharged into a small creek which had negligible flow during summer.

During discharge in non-storm periods, a fan-shaped area of turbid water could be observed extending into San Francisco Bay near the terminus of the creek. Orders were first given in 1971 to cease the water treatment plant waste discharge, including alum sludge. Sludge dewatering facilities were ultimately constructed by 1975.

GRW Engineers and their associate consultant (1982) evaluated the effects of the Paducah Water Treatment Plant wastewater discharge on the quality of the Ohio River in Kentucky. The water treatment plant has a 45 ML/d design capacity, which represents only 0.04% of the minimum river flow. Assuming that sedimentation basin sludge withdrawal represents 1% of the water treatment plant flow, the corresponding waste discharge would be only 0.0004% of the minimum river flow (250,000:1 dilution). With such a large dilution, calculated mass increases of river suspended solids were negligible and calculated increases in heavy metal concentrations were well below surface water quantity standards. It was concluded that the discharge of the water treatment plant sludge to the river apparently would not significantly increase the pollution load or affect any other conditions that could be considered harmful or contributing to degradation of water quality. The study did not indicate at what levels such effects might be significant.

As part of this study, a questionnaire was sent to most states in the USA. Of 20 responses, only two indicated adverse effects of alum sludge discharges were recognized or observed; however, no scientific documentation of the effects was provided. South Carolina (1983) indicated that there had been some indication of an adverse impact to the benthic community within a stream due to sludge accumulation.

Controlled discharge was then implemented to reduce or eliminate the impact. West Virginia (1983) indicated that the state has recognized adverse impacts both in visual problems associated with plumes and effects on habitat and food chain interferences caused by the deposition of alum sludge on the stream bottom.

3.2.1 Aluminum Toxicity

Everhart and Freeman (1973) reported acute mortalities of rainbow trout at dissolved aluminum levels of 5.2 mg/L. Toxic effects for suspended aluminum were determined at lower concentrations than dissolved aluminum. Concentrations of suspended aluminum as low as 0.52 mg/L at pH 7 were found to be actuely lethal in bioassay tests. Concentrations of aluminum in alum sludge may account for over 5% of the total solids (Inhoffer and Doe, 1973; Nelson et al., 1973). For a 1.0% TS sludge, the aluminum concentration may, therefore, be over 500 mg/L or 1,000 times greater than the reported lethal concentration. This indicates that the toxic effects of aluminum hydroxide sludge may be significant in some cases, even after full dilution. The effects may be even more significant if sludge is discharged in slugs, as commonly practised at water treatment plants, and before the sludge receives complete mixing in the receiving water.

Helliwell etal. (1983) investigated an algal assay technique to determine the effect of the chemical form of aluminum on toxicity in a synthetic hard water. The study was initiated because of concerns about lake acidification and the associated mobilization of dissolved aluminum from sediment and suspended matter, possibly causing fish dealths at pH 4.5 to 6.0.

The study concluded that:

- maximum toxicity occurred at pH 5.8 to 6.2 where as little as 5 ug/L of labile aluminum significantly inhibited algal growth;
- the presence of complexing agents in nutrient solutions greatly reduces aluminum toxicity;
- $Al(OH)_3$ did not contribute significantly to the toxicity of aluminum towards algae, but $Al(OH)_2^+$ or the combination of $Al(OH)_2^+$ and $Al(OH)^{2+}$ did; and
- dissolved aluminum appears highly toxic to algae in natural fresh waters which are slightly acidic and low in organic matter and nutrients.

3.3 HEALTH EFFECTS

Currently, there are no limits on the concentration of aluminum in drinking water. The United States Environmental Protection Agency is considering establishing limits and the American Water Works Association has indicated a goal of 0.05 mg/L (AWWA, 1983).

According to AWWA (1983), in recent years aluminum has become associated with neurotoxic effects, particularly in dialysis patients. This can lead to the development of senile dementia. Aluminum has also been implicated with Alzheimer's disease. However, research on aluminum in association with these diseases is not conclusive.

Discharges of alum sludge to a receiving water, and subsequent downstream intake in diluted form, might possibly lead to an increase in the aluminum content of the downstream system's treated water. However, there do not appear to be any research findings which indicate if this might pose a problem.

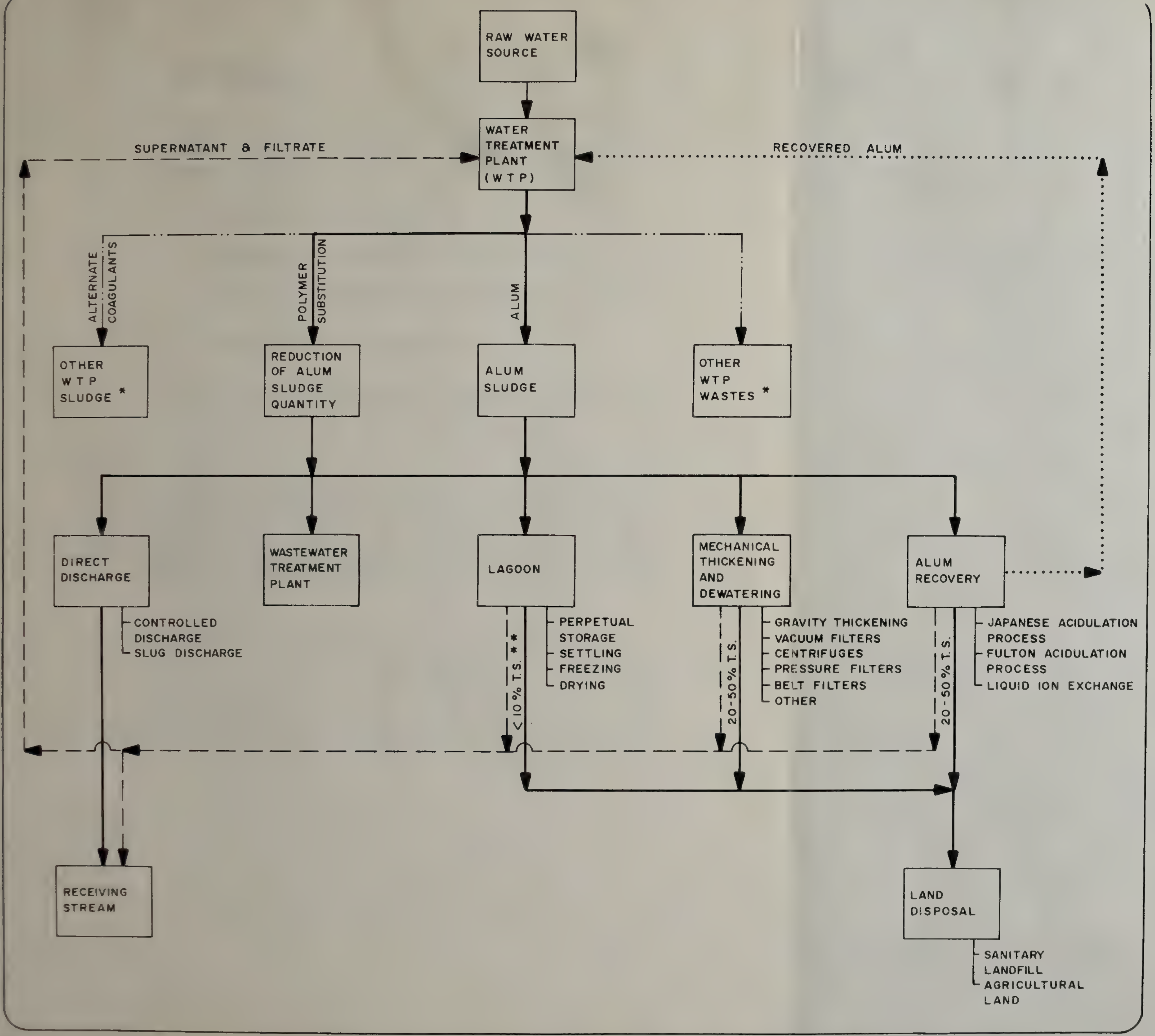
4.0 TREATMENT AND DISPOSAL OPTIONS

There are numerous methods of handling and disposal of alum sludge from water treatment plants. The methods span a wide range of complexity and cost.

The simplest and least expensive method of alum sludge disposal is direct discharge to the receiving water, that is, to the raw water source downstream of the water treatment plant raw water intake. This disposal method is no longer considered to be an acceptable option in some parts of Canada and most of the United States.

Where direct discharge is considered to be unacceptable, more complex options must be considered. The most complex of these options probably is associated with alum recovery, whereby the majority of the spent aluminum hydroxide in the alum sludge is re-converted to aluminum sulphate for re-use at the water treatment plant. This may or may not be the most expensive option. Cost savings achieved through replacement of most of the fresh alum with recovered alum may more than offset the associated increased operating costs.

The preceding alum sludge treatment and disposal options, as well as others of intermediate complexity, are illustrated in Figure 4-1. These options are also described in greater detail in Sections 4.1 to 4.8.



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ALUM SLUDGE TREATMENT and DISPOSAL

LEGEND

———	ALUM SLUDGE
—··—··—	OTHER WTP SLUDGE AND WASTES
— — — —	SUPERNATANT, FILTRATE
··········	RECOVERED ALUM

NOTES

*	OTHER WTP SLUDGE AND WASTES ARE BEYOND THE SCOPE OF THIS REPORT
**	PERPETUAL STORAGE LAGOONS DO NOT HAVE SLUDGE REMOVAL; T.S. CONCENTRATION IS GREATER WITH FREEZING AND/OR DRYING

ALUM SLUDGE TREATMENT AND DISPOSAL OPTIONS

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Figure 4-1

4.1 DIRECT DISCHARGE

Direct discharge of water treatment plant alum sludge to a stream is generally permitted in most provinces and some states. Direct discharge is a viable option where:

- regulations allow the practice;
- environmental effects are negligible or minimal;
- aesthetics and downstream water users are not adversely affected; and/or
- costs of alternate management options are prohibitive.

In some provinces and states, alum sludge discharges are reviewed on a case-by-case basis with consideration of the above factors.

It appears obvious that the easiest regulatory position to take would be to prohibit untreated alum sludge discharges. However, such a position may lead to questionable benefits and pose a financial burden on municipalities and government funding programs.

The State of Kentucky (1983) aptly expressed this point of view in explaining why they formulated a revised policy permitting direct discharges in some cases. They indicated that "of particular concern was the potential for expenditures for facilities without improvements to stream quality".

4.2 ALTERNATE COAGULANTS

An alum sludge disposal problem could be avoided if alternate coagulants are effective at a water treatment plant under consideration (James and O'Melia, 1982). The problem is then transformed into one which may or may not be more manageable, i.e. disposal of a different type of sludge. Alternate coagulants which may be considered include:

- ferric chloride;
- ferric sulphate;
- ferrous sulphate;
- lime;
- polymers acting as primary coagulants; and
- sodium aluminate

Generally, iron sludges are dewatered more easily than alum sludges. Replacement of alum with iron coagulants could reduce the problems and costs of sludge dewatering and disposal. However, iron coagulants are produced principally in eastern Canada and the USA; their availability may be limited and their cost relatively high in Alberta.

4.3 REDUCTION OF ALUM SLUDGE QUANTITY

The problem of alum sludge disposal may be reduced through reduction of the amount of alum sludge requiring disposal. This reduction in generated solids may be achieved in a number of ways:

- pretreatment of water (e.g. raw water storage pond) to remove some of the sediment load prior to alum treatment;

- substitution of a small amount of polymer, or other chemicals, for a larger amount of alum;

- improvements to coagulation/flocculation facilities may assist in decreasing alum dosages;
- since alum coagulation is pH dependent, optimization of pH with other chemcials may lead to reduced alum dosages and reduced sludge quantities; and
- preheating of water, during winter operation, may be effective in reducing alum requirements.

An obvious requirement of these methods is that treated water quality be maintained at an equivalent or higher standard. This would require consideration on a case-by-case basis.

4.4 DISPOSAL WITH WASTEWATER

Disposal of alum sludge at a wastewater treatment plant, in certain cases, may be the best management option. Krasauskas (1969) reported that 8% of surveyed plants from the 100 largest cities in the United States discharged water treatment plant sludge to sanitary sewers.

Disposal of alum sludge to wastewater treatment plants has been reported to have both beneficial and adverse effects, as summarized in Tables 4-1 and 4-2.

TABLE 4 - 1

REPORTED BENEFICIAL OR NEGLIGIBLE EFFECTS OF ALUM SLUDGE ON WASTEWATER TREATMENT PLANTS

		References*
1.	No adverse effects with controlled loading on WWTP	(1) - (5)
2.	Improved primary treatment	(3)
3.	Improved secondary treatment	(6) - (7)
4.	Improved dewaterability of wastewater sludge	(7)
5.	Improved phosphorus removal	(7)

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* References:

(1) Krasauskas, 1969
(2) Krasauskas and Streicher, 1969
(3) Wilson *et al.*, 1975
(4) AWWA, 1972
(5) Hutchison *et al.*, 1973
(6) Salotto *et al.*, 1973
(7) Hsu and Pipes, 1973

TABLE 4 - 2

REPORTED ADVERSE EFFECTS OF ALUM SLUDGE ON WASTEWATER TREATMENT PLANTS

		References*
1.	Concern over sludge deposition in sewers if TS concentration exceeds 1.0%	(1)
2.	May exceed hydraulic capacity of existing sanitary sewers	-
3.	Greater sludge production at WWTP	(2)
4.	Reduced concentration of primary sludge	(3) - (4)
5.	May upset digesters at excessive aluminum concentration	(2) - (5)
6.	Require greater digester capacity	(6)
7.	Greatly reduced solids concentration of digested sludge	(3)
8.	Increased solids loading increases capacity requirements for sludge thickening and dewatering equipment at the WWTP	(5)
9.	Problems experienced with sludge dewatering where alum sludge is discharged as a slug	(7)

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* References:

(1) Neilsen, 1977
(2) Hsu and Pipes, 1973
(3) Wilson _et al._, 1975
(4) Salotto _et al._, 1969
(5) Fulton, 1969
(6) AWWA, 1972
(7) Krasaukas and Streicher, 1969

There appears to be only limited quantitative information on levels of alum sludge which can be discharged safely to a WWTP. Hsu and Pipes (1973) presented the following information, which was based on laboratory test results:

- When the concentration of aluminum hydroxide in wastewater sludge is higher than 100 mg/L as Al, anaerobic digestion will be affected.
- Dosages of aluminum hydroxide to an activated sludge aeration tank yielding concentrations in the range of 10 to 300 mg/L as Al will cause significant increase in phosphate removal, no change in nitrification, and a slight increase in COD removal.
- Dosages of aluminum hydroxide greater than 100 mg/L as Al to primary settling tanks result in overall reduction of "free" phosphate to about 0.5 mg/L in a secondary treatment plant.

Wilson *et al.* (1975) concluded that alum sludge dosages of at least 40 mg/L (or 100 mg/L fresh alum) could be handled without significant difficulty at a WWTP. At sufficient dosages, primary SS removals in excess of 80% were achievable.

Hsu and Pipes (1973) presented two suggestions concerning WTP alum sludge disposal at a WWTP.

1) *Discharge alum sludge into an existing sewer at a low rate.* Maximum suggested concentration of aluminum hydroxide in wastewater is 70 mg/L as Al for primary settling, or 23 mg/L as Al in the aeration tank. These concentrations will increase the treatment efficiency of these two units but are low enough to keep sludge production at a reasonable level.

2) Discharge the waste into a separate sewer going to a thickener at the WWTP. Mix the concentrated underflow with regular digested sludge to improve sludge dewatering. Discharge the supernatant, which may contain a small amount of aluminum hudroxide, to the primary settling or aeration tank to increase the efficiency of these units.

4.5 LAGOONS

Various types of lagoons have been used to facilitate the disposal of alum sludge. These include:

- perpetual storage lagoons,
- settling lagoons,
- natural freeze-thaw conditioning and dewatering lagoons, and
- drying lagoons.

A particular lagoon system may be designed or operated to serve one or more of the above functions.

4.5.1 Perpetual Storage Lagoons

Of the four types or functions of lagoons, only the perpetual storage lagoons can be considered as an ultimate disposal method. However, it would be difficult to consider this type of system as a "management" option. The most significant drawback with this method is the large land area required for new sludge lagoons when the old ones fill up. Such an approach might be considered as "mismanagement" except for very small systems since valuable land resources are needlessly consumed for additional lagoon area.

An interesting local example illustrates the general futility of this method of alum sludge management. An alum sludge holding pond was constructed along with a new WTP for an Alberta town. The town apparently was not aware of any requirement to remove sludge from the lagoon, in effect rendering it the perpetual storage type. When the lagoon filled with WTP sludge a few years after operation, the problem of removing and disposing of the large sludge accumulation appeared horrendous and expensive. Rather than construct additional sludge lagoons, the Town elected to discharge future amounts of alum sludge directly back to the river.

4.5.2 Settling Lagoons

Long-retention lagoons may be used for settling of alum sludge. Supernatant from the lagoons is discharged either back to a receiving stream or to the WTP. Settled sludge must be removed periodically, by pumping or drag line, and then hauled for ultimate disposal. Disposal of the wet sludge can either be to a WWTP for further treatment or to the land for ultimate disposal and beneficial use.

Disposal may be a problem because of:

- high costs of hauling fairly dilute sludge;
- WWTP receiving the sludge would require adequate capacity and perhaps equalization facilities;
- the gelatinous sludge poses handling problems;
- wet sludge may not be accepted at a sanitary landfill and, if it is, then it could cause landfill operating problems; and
- land disposal by incorporation into the soil may not be appropriate.

To minimize the problem of wet sludge disposal, settling lagoons may be operated in conjunction with two addition methods:

- natural freeze-thaw conditioning and dewatering, and/or
- drying.

These methods are described in Sections 4.5.3 and 4.5.4.

Bishop and Fulton (1968) presented data on a 4.3 m deep alum sludge lagoon at the Shoremont WTP, New York. After five years of operation and an accumulated sludge depth of about 2.7 m, suspended solids were reported to range from about 1.7% in the top sludge layer to about 10% at the bottom. Most of the sludge was in the 6 to 7% solids range. It was concluded that sludge can be concentrated from 0.5% to an average of about 6% suspended solids at the Shoremont lagoon.

Neubauer (1968) presented data on the Shoremont lagoon as well. It was indicated that total solids (not suspended solids) concentration usually increased with depth, from about 1.7% at the sludge interface to a maximum of 14% at the lagoon bottom. Typical bottom concentration was about 10%. Suspended solids comprised 91% of the total solids; volatile solids were about 27% of the total solids. The average total solids concentration was determined to be 4.3%, lower than the 6% suspended solids figure reported by Bishop and Fulton (1968) for the same lagoon.

Neubauer (1968) also presented data on the effluent (supernatant) from the Shoremont lagoon. BOD and COD were below 20 mg/L and suspended solids were slightly greater.

4.5.3 Natural Freezing

Several papers have commented on the very substantial changes in alum sludge properties when the sludge mass is completely frozen and then thawed (Albretch, 1972; Bishop and Fulton, 1968; Doe, 1968; Farrell et al., 1970; Krasauskas, 1969; Krasauskas and Streicher, 1969; Mahoney and Duensing, 1972; and Wilhelm and Silverblatt, 1976).

The main effect freezing has on the sludge is the removal of hydration water, thereby increasing the solids settleability and concentration. Frozen and thawed sludge has been described as having solids with the appearance of coffee grains (Doe, 1968). Other benefits of the freeze-thaw process are improvements in the filterability of sludge and the relative ease at which it can be dried further. Reported changes are summarized in Table 4-3.

There does not appear to be a general concensus on the design and operation methods for natural freeze-thaw lagoons. It appears that the designer/operator may wish to consider three basic systems:

1) Freezing of one layer - Alum sludge would be settled in a lagoon and decanted prior to winter freezing. The remaining sludge depth must be shallow enough to ensure complete freezing. Snow cover may require periodic removal if its insulating effect prevents complete freezing. Upon thawing in spring, the supernatant is decanted or drained through the sludge and a gravel bed. The remaining sludge is allowed to dry further in the sun prior to its removal for ultimate disposal, perhaps at a landfill.

TABLE 4-3

EFFECT OF FREEZE-THAW ON ALUM SLUDGE

PARAMETER	EFFECT	REFERENCE
Total Solids	Increased from 2% to 20.2% after gravity settling and 33.9% after filtering	AWWA, 1969
Total Solids	Increased from 3.5% to 17.5% after gravity settling and readily drained and dried on sand filter to consistency easily handled	Bishop & Fulton, 1968
Freezing Rate	Approximately the same as water	Farrell *et al.*, 1970
Dewaterability	Improves with slow freezing	Farrell *et al.*, 1970
Dewaterability	Solids immediately settled upon thawing and the clear water drained freely through solids and gravel bed	Mahoney & Duensing, 1972
Total Solids (Four locations)	Increased from 1.5 - 7 wt% to 19 - 22 wt% after settling for 1 - 5 h.	Wilhelm & Silverblatt, 1976
Design Vacuum Filtration Rate (Four locations)	Increased from 1.0 - 5.9 kg/h/m^2 to 150 - 730 kg/h/m^2	Wilhelm & Silverblatt, 1976
Total Solids Concentration after Vacuum Filtration (Four locations)	Increased from 12 - 21 wt% to 25 - 34 wt%	Wilhelm & Silverblatt, 1976

2) Freezing in layers - Where land availability or economics dictate, freezing of sludge in layers may be preferred. Lagooned sludge would be pumped periodically to the surface of a freezing pond which would be flooded in 100 - 200 mm layers. After complete freezing, the next flooding could occur. In this way, an overall frozen depth of 1 - 2 m could be obtained, provided that the winter temperatures are sufficiently cold and prolonged. Subsequent drainage, drying and removal of sludge could be accomplished as in 1). Advantages of this method include minimal land requirement and melting of insulating snow accumulations with subsequent floodings. Disadvantages include greater operational requirements.

3) Annual Freezing without Removal of Dewatered Sludge - Doe (1968) described a system utilizing large lagoons for natural freezing at Copenhagen. It appears that this system operated without sludge removal. It was reported that "vegetation begins to grow on the surface after a time, and eventually grass grows over it before the next lot of sludge goes onto it".

If the type of system described by Doe is functional over many years, then perhaps it could be considered as an ultimate disposal method as well. In effect, the freeze-thaw lagoon would function as a sludge landfill. This would circumvent the need to remove sludge annually and thereby reduce operating costs. Ultimately the land may be covered with suitable soil, re-vegetated and returned to its original use or an alternate use (e.g. recreation).

It appears that the type of system described by Doe would require good underdrainage to remove excess moisture from the lower sludge layers.

4.5.4 Drying Lagoons/Beds

Dewatering of alum sludge in drying lagoons involves evaporation at the sludge surface. Results can vary widely depending upon the location and time of year. Drying lagoons or beds are most ideally suited to areas with lots of sunshine, warm weather and low precipitation.

Young (1968) reported that drying beds seldom have been successful in handling hydroxide sludges. In addition to surface evaporation, drying beds rely on drainage through a porous underdrain which generally becomes clogged.

Novak and Langford (1977) reported that problems of solids penetration into the bed or poor drainage can be overcome by polymer conditioning prior to application. Data were presented on estimates of bed area for satisfactory drainage and drying.

4.6 MECHANICAL THICKENING AND DEWATERING

There are various mechanical methods of concentrating alum sludge to facilitate its ultimate disposal.

The first step usually involves thickening the sludge to a 2-6% concentration. The thickened sludge has a smaller volume than the dilute sludge and is more readily dewatered in subsequent processes.

There appears to be general agreement that alum sludge should be dewatered to about a 20% TS concentration if it is to be readily landfilled. Westerhoff and Daly (1974) suggested that alum sludge of between 20 to 40% solids should be combined with other material in the ultimate disposal process, e.g. combined with solid waste in a sanitary landfill. They also suggested that, at 40% solids, the dewatered sludge is sufficiently dry to be placed in a landfill consisting solely of sludge. James (1983) indicated that this type of sludge was used as a cover material at a sanitary landfill in Atlanta, Georgia.

Of the references reviewed, there was no comment on possible freezing problems during transport of sludges containing higher water contents. Perhaps this could be a problem in cold climates.

Various references have indicated that the solids content of dewatered sludge is not the sole criterion indicative of its apparent dryness, handleability or ease of disposal. For example, Cope (1983) reported that people visiting the Hemphill Settled Solids Facility in Atlanta, Georgia often remarked that that sludge seemed drier than that from the Chatahoochee facility, even though the latter typically had a higher solids content. Also, Novak and Calkins (1975) stated that solids concentration of a sludge is a poor indication of its handleability.

The principal types of equipment used for dewatering alum sludge include:

- vacuum filters,
- centrifuges, and
- pressure filters (filter presses).

Belt filters have also been tested, although with relatively poor performance. For descriptions of these types of dewatering equipment, the reader is referred to various sanitary engineering texts and manufacturers' catalogues.

Reported experience with alum sludge thickening and dewatering with various types of mechanical equipment is presented in the following sections.

4.6.1 Gravity Thickening

In this report, thickening is considered to be an initial concentration step for dewatering sludge. Gravity sludge thickening is the only process addressed in this section, as it is the most common method for thickening alum sludge. No information was readily available on the applicability of dissolved air flotation as a possible thickening method for alum sludge. Other methods such as centrifuging have been suggested as a viable thickening method, prior to further dewatering. This method is covered under "dewatering" in Section 4.6.3.

Thickening of alum sludge prior to subsequent dewatering is important for a number of reasons, e.g.:

- reduction of hydraulic loading on subsequent dewatering equipment,
- improvement in filterability of the sludge, and
- reduction of overall capital and operating costs.

With respect to the second point, Hawkins et al. (1974) presented data showing significant improvements in the filterability of alum sludge at concentrations over 2%. The improvements were measured in terms of specific resistance, which is a measure of the resistance of the sludge to filtration.

The apparent explanation of this phenomenon is that, with very dilute solutions, particles will either enter a filter pore or cover the pore opening, thereby blinding the filter. At higher solids concentrations, particles can be blocked by each other as they attempt to enter the pore simultaneously, and filter media resistance therefore does not increase as much during cake formation.

It appears that alum sludge generally can be thickened to a concentration of 2% or more. Gruninger and Westerhoff (1974) and Gruninger (1975) concluded that gravity thickening was effective in increasing the concentration of an alum-clay sludge from 0.1-3% to 2% or more. Concentrations as high as 6% were obtained with a 2 h thickener retention time. They also concluded that polymer addition prior to gravity thickening can enhance alum sludge settling characteristics. Smaller thickening tanks can thus be used.

Kos (1977) recommended design and operating conditions for thickening of alum sludge containing some powdered activated carbon:

- suspended solids loading - 15-24 kg/m^2/h,
- tank depth - 2.4 m with 1.5 m thickening zone, and
- thickened sludge concentration - 2.5-3.0%.

Foster (1975) reported an average thickener underflow concentration of 9% at the Hemphill plant in Atlanta, Georgia. The thickeners were designed for a surface overflow rate of about 1.2 mm/s. A lower overflow rate was considered to be more effective.

4.6.2 Vacuum Filters

There have been several reports of dewatered solids contents of 20% or more after vacuum filtration (Bishop, 1978; Gruninger, 1975; Mahoney and Duensing, 1972; Neubauer, 1968; and Nielsen et al., 1973). Usually it is necessary to precoat the vacuum filter with 50 to 100 mm of diatomaceous earth, or other suitable material, to prevent filter blinding. During operation, it is also necessary to use a finely adjusted blade to remove a small portion of the precoat from the outside surface of the drum along with dewatered sludge. This exposes fresh precoat to additional sludge. When the precoat has been used up, the cycle is repeated.

Vacuum filtration is sensitive to the quality of the raw sludge. Better success has been observed with larger amounts of inert solids in the sludge (Bishop, 1978). Chemical conditioning with polymers or lime may also be necessary, although the former is not always beneficial (Mahoney and Duensing, 1972).

Adequate filtration has been experienced at feed rates up to 204 $L/h/m^2$ (Gruninger, 1975; Mahoney and Duensing, 1972).

4.6.3 Centrifuges

Scroll centrifuges occasionally have been successful in dewatering alum sludge to a 20% concentration (Bishop, 1978; Gruninger, 1975; Nielsen et al., 1973; Westerhoff and Daly, 1974). As with vacuum filters, better dewatering is possible if the sludge contains higher concentrations of inert solids. Basket centrifuges have proven incapable of dewatering alum sludge to 20% solids (Krasauskas and Streicher, 1969; Neubauer, 1968).

Chemical conditioning with polymers (about 1-4 kg/tonne solids) is usually necessary.

4.6.4 Pressure Filters

Pressure filters (filter presses) are capable of the highest level of dewatering relative to the other conventional mechanical equipment. Reported dewatered solids concentrations typically range from 30 to 50% (Foster, 1975; Gruninger, 1975; Krasauskas, 1969; Westerhoff and Daly, 1974).

Pressure filters are operated in batches. Usually the filter is first precoated with diatomaceous earth, although other precoats have been tried (e.g. fly ash and peralyte). Before application to the precoated filter, the alum sludge is usually conditioned with lime to raise the pH above 11.0. Polymers have also been used in conditioning the sludge. Filter pressures in the order of 1,400 kPa assist in dewatering the sludge to a relatively dry state. At the end of the cycle, the cake is discharged from each filter plate to a conveyer or holding bin and then hauled to disposal.

There are several plants with pressure filters for dewatering alum sludge in the United States. Two of these plants located in Atlanta, Georgia were visited by the consultant. Specific information on these facilities is presented in Appendix C.

4.6.5 Belt Filters

Experience with belt filters generally has been poor in attempts to dewater alum sludge. It appears that it is not possible to dewater the sludge to 20% solids, even with high polymer dosages (Bishop, 1978; Gruninger, 1975). In addition filtrate quality can be poor, creating disposal problems.

4.6.6 Pellet Flocculation Process

The pellet flocculation process has been used successfully to dewater alum sludge in Japan (Bishop, 1978). The process is reported capable of producing sludge with 25 to 30% solids. The process involves multistage thickening of the sludge, chemical treatment using sodium silicate and a polymer, and a dewatering process using a large horizontal rotating drum (dehydrum). Oil-fired dryers may also be used to dry the sludge further.

4.6.7 Other Dewatering Processes

Olson (1976) described a proprietary process termed B.E.S.T. (basic extractive sludge treatment). The method is reported to deliver 95% solids or more. The process utilizes a solvent which conditions the sludge and enhances its dewatering and separation properties.

4.7 LAND DISPOSAL

There are two basic methods which may be considered for land disposal of water-treatment-plant alum sludge: disposal at a sanitary landfill or disposal on agricultural land. Sanitary landfill disposal is a common method, whereas agricultural land disposal appears to be uncommon.

4.7.1 Sanitary Landfill

Sanitary landfills have been used for the disposal of dilute, thickened and dewatered alum sludges.

Both dilute (unthickened, less than 2% TS) and thickened (2-6% TS) alum sludge can create operational problems at landfills. Because of its high water content, this sludge can greatly hamper the operation of landfill equipment due to "muddy" conditions it creates. For this reason, many landfills refuse to accept this type of waste, or have segregated disposal areas for certain types of liquid wastes. The latter would appear to be a feasible approach only if quantities are quite small.

As previously indicated in Section 3.5, the impact of alum sludge disposal in landfills may be high if the leachate pH is acidic. This may tend to redissolve some of the heavy metals contained in the sludge. However, landfills should have proper leachate containment to ensure groundwater contamination problems do not develop.

The State of Conneticut (1983) conducted tests on alum sludge leachate from sand drying bed underdrainage. They concluded that alum sludge is not a hazardous waste under acid leachate conditions. The only metals which leached on occasion at slightly elevated levels were barium and selenium. Surrounding groundwater monitoring wells are required to measure any impacts, should they develop.

4.7.2 Agricultural Land

The Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (Alberta Environment, c.1982) give no specific limits for aluminum in sludge. Guidelines for water-treatment-plant sludge have not been formulated. Disposal of water-treatment-plant alum sludge on agricultural land may be a viable option, in some cases. Sludge application would have to be restricted to certain times of the year. Both subsurface injection and surface application are possible methods of applying the sludge. Surface application should probably be followed, as soon as possible, by tillage.

Rengasamy et al. (1980) reported on successful experiments with water treatment plant alum sludge applications to three types of soil: a strongly sodic clay, a leached lateritic sand from a podzol deficient in trace elements, and the surface horizon of a hard-setting red-brown earth. Soil pH was 7.5, 6.1 and 5.1, respectively. Alum sludge pH was 6.5. The sludge application proved beneficial in several ways:

- decreased both slaking and dispersion of soils;
- improved soil aggregation;
- increased water retention;

- decreased strength of aggregates and modulus of rupture of molded briquettes; and
- increased yield of maize with and without fertilizer.

The addition of sludge did not cause any marked change in the pH values of the soils.

At high application rates, germination problems developed and phosphate uptake by the maize decreased. It was concluded that alum sludge has beneficial effects on soil structure and plant growth, but requires field testing at rates in the order of 2 t/ha (dry weight of sludge).

Currently, research is being conducted at the New Haven Agricultural Experimental Station in New Haven, Conneticut on land application of alum sludge. Possible beneficial uses in the nursery potting soil industry are being examined (Conneticut, 1983).

4.8 ALUM RECOVERY

The disposal problems with alum sludge can be greatly reduced by first recovering alum from the sludge prior to sludge disposal. The recovered alum can then be re-used in the water treatment process. Cost savings are associated with reductions in fresh alum requirements, relative ease of dewatering nearly aluminum-free sludge, and reductions in the volume of sludge for ultimate disposal. These savings may offset a portion of the overall operating costs.

Alum recovery has been practised at some water treatment plants in Japan. Also, at one time, it was practised at the Tampa WTP (Robberts and Roddy, 1960). Alum recovery is no longer practised at the Tampa WTP (Westerhoff, 1972; Fulton, 1983), nor is it currently practised anywhere in the USA (Doe, 1983).

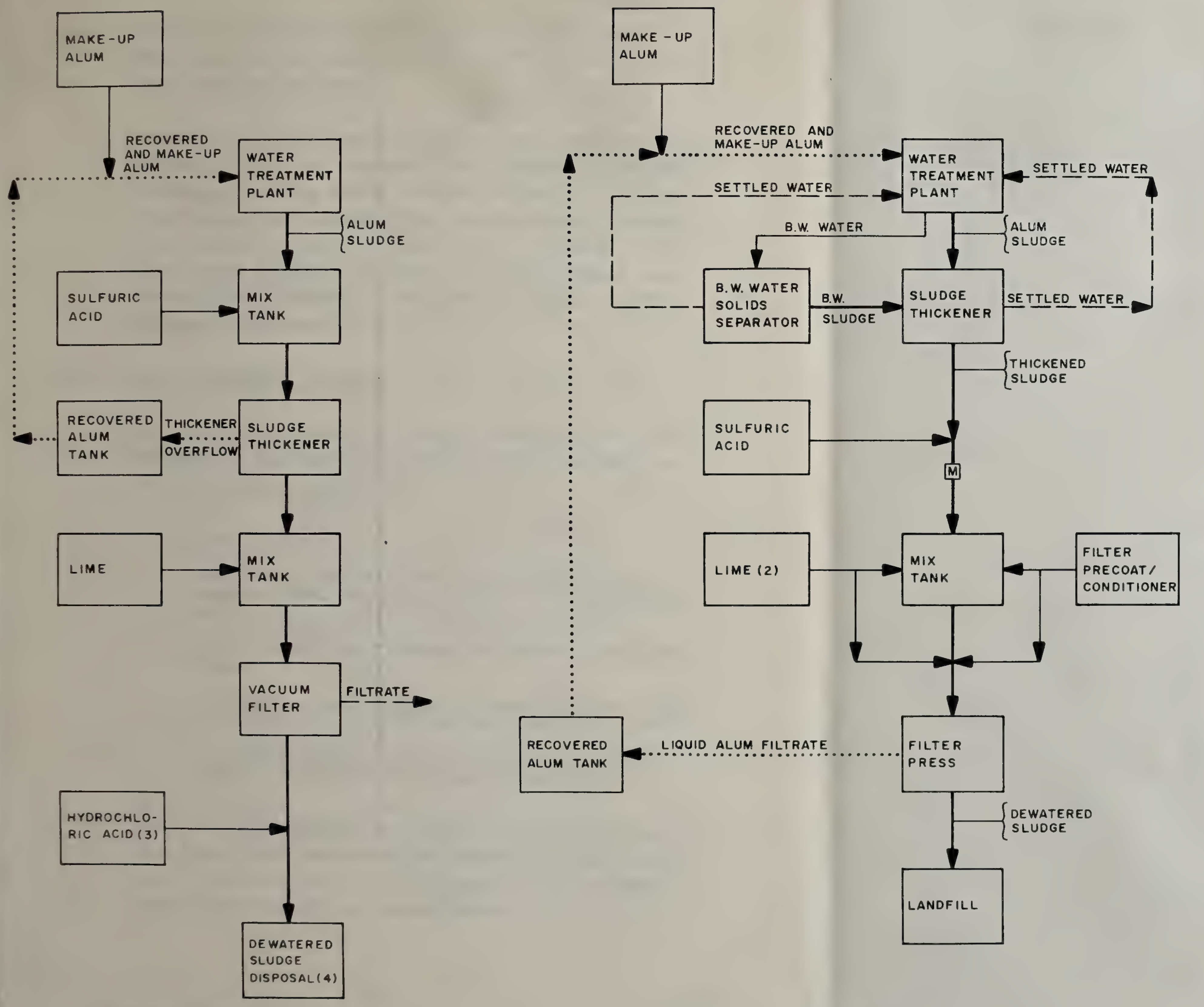
Concerns with respect to possible recycling of heavy metals and organics in water treatment processes have retarded the implementation of alum recovery at USA and new Japanese plants. It appears that these concerns have not yet been justified through any research findings. If the concerns prove valid, then re-use of recovered alum at wastewater treatment plants to improve performance and/or phosphorus removal, may be preferred as an alternative.

There are various processes which may be considered for alum recovery. Three of the more common processes are described in Sections 4.8.1 to 4.8.3. The first two processes involve acidulation of alum sludge with sulfuric acid to convert $Al(OH)_3$ to alum; the latter process involves liquid ion exchange.

4.8.1 Japanese Acidulation Process

The Japanese acidulation process for alum recovery is illustrated in Figure 4-2. The process generally consists of:

- mixing of sulfuric acid with alum sludge;
- thickening of acidulated sludge;
- reclaiming alum from thickener overflow;
- conditioning of thickened sludge with lime;
- dewatering of conditioned sludge with vacuum filters;
- pH adjustment of dewatered cake with HCl; and
- haulage of sludge cake to cake yard.



JAPANESE PROCESS
(Fujita, 1967)

FULTON PROCESS [1]
(Fulton, 1974)

Alberta
ENVIRONMENT

ALUM SLUDGE TREATMENT and DISPOSAL

LEGEND

━━━━━━	SLUDGE
············	RECOVERED ALUM
— — — —	FILTRATE, SUPERNATANT
――――――	OTHER
M	IN LINE MIXER

NOTES

1. PATENTED PROCESS (Metcalf and Eddy) CAPABLE OF TWO OPERATING MODES: ALUM RECOVERY & SLUDGE DEWATERING.
2. IN ALUM RECOVERY OPERATING MODE, LIME IS FED AT END OF FILTER RUN TO NEUTRALIZE THE SLUDGE CAKE BEFORE IT IS RELEASED.
3. PURPOSE OF HYDROCHLORIC ACID NOT INDICATED.
4. SLUDGE DISPOSAL TO "CAKE YARD."

ALUM RECOVERY BY ACIDULATION (Fulton and Japanese Process)

the UMA group
Underwood McLellan Ltd.

Figure 4-2

A preliminary thickening step could also be considered above. The process is reported to recover 50 to 80% of the alum from the sludge (Fulton, 1969).

Impurities such as metals and TOC are recycled and concentrated in the recovered alum. However, these are discharged from the system in higher proportions at lower alum recovery efficiencies. The concentration of reclaimed alum solution fluctuates (Tomono, 1977). If recovered alum is of lower strength, then this may cause filtered water turbidity and aluminum concentration to increase slightly (Westerhoff and Daly, 1974).

4.8.2 Fulton Acidulation Process

An innovative process for solids dewatering and alum recovery was developed by G.P. Fulton, Metcalf and Eddy Inc. The Fulton process consists of:

- sludge thickener;
- conditioning of thickened sludge (with lime in dewatering mode or with sulfuric acid in recovery mode);
- pressure filter (with precoat) to dewater conditioned sludge;
- in dewatering mode, disposal of dewatered alum sludge to landfill and return of filtrate to head of WTP; and
- in recovery mode, disposal of dewatered sludge to landfill and collection of recovered alum filtrate.

The process is flexible in that it provides for dewatering of alum sludge with and without the recovery of alum (Figure 4-2). The efficiency of alum recovery is also greatly improved over that for the Japanese process.

Along with increased recovery, metals and TOC may be concentrated further in the recovered alum. This may necessitate periodic wastage of recovered alum or operation in the dewatering mode to keep contaminants within acceptable levels.

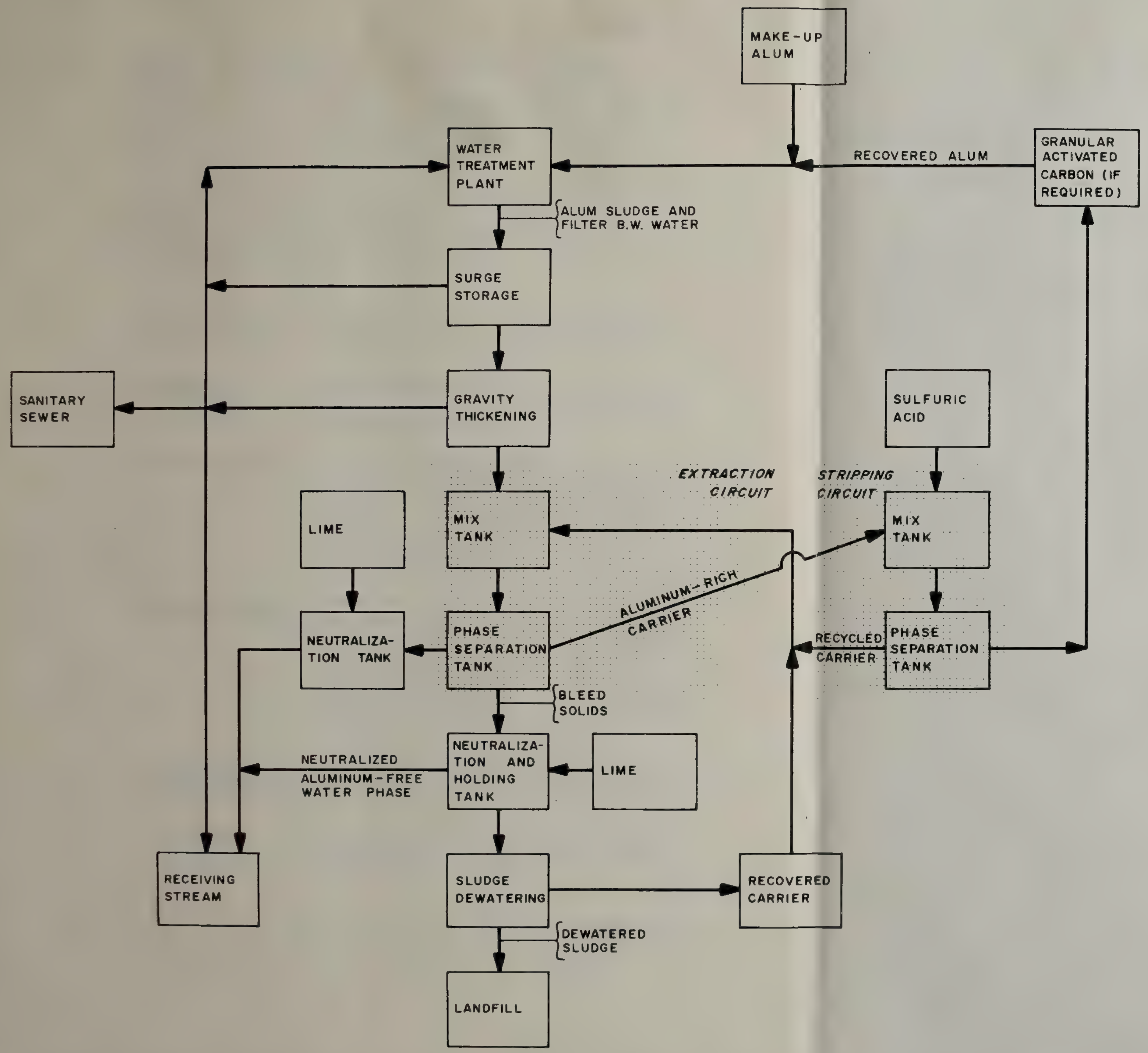
Other differences between the Japanese and Fulton alum recovery processes include:

- recovered alum from thickener overflow (Japanese process) versus filtrate from pressure filter (Fulton process).
- need for acid-resistant dewatering equipment with Fulton process.
- possible increased hazards with Fulton process if pressure filter accidentally leaks or sprays acidified sludge.

The Fulton process is patented, although there are no fees charged for its use. The process is reported to result in only a marginal capital cost increase (above the cost for dewatering) to permit alum recovery (Fulton, 1983). The process was incorporated at the alum sludge dewatering facility at Jersey City, New Jersey at a marginal capital cost increase of approximately $100,000. However, to date the plant has not practised alum recovery.

4.8.3 Liquid Ion Exchange Process

A patented process of recovering alum through liquid ion exchange (solvent extraction) has been suggested as a promising method in several recent papers (Cornwell, 1979; Cornwell and Lemunyon, 1980; Cornwell *et al*., 1981; Westerhoff and Cornwell, 1978). Figure 4-3 illustrates the process.



Alberta
ENVIRONMENT

ALUM SLUDGE
TREATMENT and DISPOSAL

ALUM RECOVERY BY LIQUID ION EXCHANGE (MODIFIED PROCESS - Westerhoff and Cornwell, 1978)

the uma group
Underwood McLellan Ltd.

Figure 4-3

To date, only laboratory and pilot plant studies have been conducted for this process using alum sludge. However, the chemical process industries have made use of solvent extraction for over twenty years to recover such metals as uranium, zinc, copper, chromium and gold.

A description of the process is covered in papers by Cornwell (1979) and Westerhoff and Cornwell (1978). In summary, the process consists of the following:

- Acidification:	thickened alum sludge is acidified to a pH of about 2 by concentrated sulfuric acid;
- Sedimentation:	liquid overflow from a sedimentation tank is dilute alum requiring subsequent treatment;
- Extraction Circuit:	the extractant (organic chemicals) reacts chemically with aluminum to form a soluble aluminum-extractant complex. An aluminum-rich carrier phase is separated from an aluminum-free aqueous phase in a separation tank;
- Stripping Circuit:	alum is produced by reacting the aluminum-rich carrier phase with sulfuric acid (stripping agent). Regenerated solvent is recovered in a separation tank for re-use in the extraction circuit. The remaining alum is then ready for re-use, perhaps after GAC filtration, if required;
- Sludge Dewatering and Disposal:	aluminum-free sludge from the extraction circuit is neutralized, dewatered and hauled to landfill; and
- Water Waste:	aluminum-free water from the extraction circuit is neutralized, then wasted.

A cost-effective modification of the above eliminates the initial acidification and settling step (Westerhoff and Cornwell, 1978).

5.0 COMPARISON OF OPTIONS

In this section, the advantages and disadvantages of various alum sludge treatment and disposal options are summarized. Cost data are also summarized where such information was readily available. The information should be used only as a general guide in evaluating alum sludge treatment and disposal options as each case is different and requires its own specific analysis of relevant factors.

5.1 DEWATERING METHODS

Advantages and disadvantages of four dewatering methods are summarized in Sections 5.1.1 to 5.1.2.

5.1.1 Vacuum Filter

Advantages

1. Can achieve cake solids close to or in excess of 20% with precoat (AWWA, 1972; Bishop, 1978; Krasauskas and Streicher, 1969; Mahoney and Duensing, 1972; Neubauer, 1968).

2. Good filtrate quality (Gruninger, 1975; Mahoney and Duensing, 1972; Westerhoff and Daly, 1974).

3. Polymer pretreatment not required (Mahoney and Duensing, 1972).

Disadvantages

1. Filter blinding may occur if vacuum is too high (Albretch, 1972).

2. Unable to filter dilute sludges effectively (Albretch, 1972; Krasauskas and Streicher, 1969).

3. As much as one-third of cake consists of precoat, when this is used (AWWA, 1972).

4. Difficulty in dewatering when inert solids concentration is low (Bishop, 1978).

5. Four to seven times more precoat required for dewatering dilute <1% sludge (Gruninger, 1975).

6. Potential for precoat cracking, falling and uneven application (Gruninger, 1975; Westerhoff and Daly, 1974).

7. Inconsistent performance (Gruninger, 1975).

8. Complex mechanical equipment and discontinuous operation with precoat (Krasauskas, 1969).

9. Short filter cloth life (Krasauskas, 1969). (Type of filter cloth may make a difference.)

5.1.2 Centrifuge

Advantages

1. Small space requirements (Albretch, 1972; Krasauskas, 1969).
2. Continuous automatic process (Albretch, 1972; Gruninger, 1975; Krausauskas, 1969; Westerhoff and Daly, 1974).
3. Ability to handle both dilute and thickened sludges (Albretch, 1972; Krausauskas, 1969).
4. Consistent performance (Gruninger, 1975; Westerhoff and Daly, 1974).
5. Little operating attention (Krasauskas, 1969).
6. Cake solids as high as 20% achieved with polymer feed (Bishop, 1978; Gruninger, 1975; Nielsen et al, 1973; Westerhoff and Daly, 1974).

Disadvantages

1. High maintenance cost (Albretch, 1973) due to abrasiveness of sand in the sludge on scroll (Nielsen, 1978). Cyclonic degritter ahead of centrifuge may extend maintenance interval (Westerhoff and Daly, 1974).
2. Basket centrifuge incapable of dewatering sludge generated from treating low turbidity raw water (AWWA, 1978b).

3. Centrate solids are predominantly fine materials which may create problems if recycled to the head of the WTP (Fulton, 1976b; Krasauskas, 1969).

4. Centrate has relatively high SS concentration (Gruninger, 1975; Westerhoff and Daly, 1974) unless cake solids are limited to about 5% concentration (Inhoffer and Doe, 1973).

5. High maintenance cost (Krasauskas, 1969).

6. Cake solids less that 20% for scroll centrifuge (Krasauskas and Streicher, 1969; Neubauer, 1968) and for basket centrifuge (Nielsen _et al._, 1973).

7. Extreme sensitivity to operating variables (Nielsen _et al._, 1973).

5.1.3 Pressure Filters

Advantages

1. Greater solids concentrations are achievable than with other mechanical dewatering equipment (AWWA, 1972 and 1978b).

2. Good filtrate quality (AWWA 1978b; Gruninger, 1975).

3. Flexibility to adapt to changing operating conditions (AWWA, 1978b).

Disadvantages

1. Process must be shut down periodically to remove cake (Albretch, 1972; Krasauskas, 1969).

2. Higher than average labour costs (Albretch, 1972; Krasauskas and Streicher, 1969).

3. Filtrate disposal may be a problem because of high pH, significant fraction of insoluble aluminum hydroxide is converted to soluble aluminate at pH 11.5, and because precoat material can contribute potentially significant concentrations of trace metals to the filtrate (AWWA, 1978b).

4. High initial equipment costs (Krasauskas and Streicher, 1969).

5.1.4 Belt Filter

Advantages

There appear to be no significant advantages with belt filters.

Disadvantages

1. Cannot dewater to 20% solids even with high polymer dosage (Bishop, 1978; Gruninger, 1975).

2. Poor filtrate quality (Bishop, 1978).

3. Moderate filtrate quality (Gruninger, 1975).

5.2 ALUM RECOVERY METHODS

Advantages and disadvantages of the two main alum recovery methods (acidulation and liquid ion exchange) are summarized in Sections 5.2.1 and 5.2.2.

5.2.1 Acidulation

Advantages

1. Significant reduction of quantity of suspended solids for ultimate disposal.
2. Solids are more readily thickened and dewatered.
3. Use of recovered alum helps to defray the cost of alum sludge treatment by reducing fresh alum requirements.

Disadvantages

1. Iron and manganese are recycled, increasing the product water concentrations of these elements.
2. Organics may be hydrolized and recycled with possible increase in trihalomethane formation.
3. Impurities in sulfuric acid may increase heavy metals.
4. Any heavy metals in the raw water would be recycled and possibly increase their concentration in the treated drinking water.
5. Hazards associated with handling sulfuric acid.

6. Potential hazard with high pressure filtration of low pH sludge (Fulton process).

7. Use of recovered alum might slightly increase filtered water turbidity and aluminum concentrations.

8. Concentration of reclaimed alum solution fluctuates (Tomono, 1977).

5.2.2 Liquid Ion Exchange

Advantages

1. Significant reduction of quantity of suspended solids for ultimate disposal.

2. Solids are more readily thickened and dewatered.

3. Use of recovered alum helps to defray the cost of alum sludge treatment by reducing fresh alum requirements.

4. Appears not to experience problems of build-up of contaminants from recycling (system is able to discharge contaminants in the process residue).

5. Process appears capable of recovering more than 90% of alum.

Disadvantages

1. Technology not proven for full-scale alum sludge dewatering.

2. Contamination of recovered alum with some extractant (such as kerosene) might be possible.

3. Complex operation.

4. Slight fire hazard with organic carrier.

5. Hazards associated with handling sulfuric acid.

6. Use of recovered alum might increase filtered water turbidity and aluminum slightly.

5.3 ULTIMATE DISPOSAL METHODS

Ultimate disposal methods for alum sludge are compared in Sections 5.3.1 to 5.3.5

5.3.1 Direct Discharge to Receiving Stream

Advantages

1. Simple.

2. Low capital cost.

3. Negligible O&M cost.

Disadvantages

1. May be detrimental to benthic and other aquatic organisms.

2. Aesthetic problem if inadequate dilution and/or low stream turbidity.

3. May increase aluminum concentration in downstream water supplies.

5.3.2 Disposal with Wastewater

Advantages

1. The sludge disposal problem is transferred away from the water utility.

2. More environmentally acceptable than direct stream discharge.

3. Sludge treatment and disposal might be undertaken more efficiently at one location rather than two.

4. May improve the performance of primary and secondary treatment processes with respect to BOD, SS and P removal.

5. May improve wastewater sludge dewatering.

Disadvantages

1. Wastewater utility may be reluctant to accept alum sludge.

2. Potential for overloading existing sanitary sewers, or clogging if solids concentrations are excessive.

3. Concentration of primary solids may decrease.

4. May overload digesters (AWWA, 1978a) and decrease digested solids concentration.

5. Sediment in alum sludge may be abrasive resulting in increased wear on pumps, etc.

6. Slug discharges may upset wastewater treatment plant.

7. Need for greater solids dewatering and disposal capacity at wastewater treatment plant.

5.3.3 Disposal in Perpetual Storage Lagoons

Advantages

1. Simple.
2. More environmentally acceptable than direct stream discharge.
3. May be low in cost relative to mechanical dewatering/land disposal alternatives.

Disadvantages

1. Large land area requirement.
2. May be applicable only to small systems.
3. Land is lost permanently (cannot be re-used or converted to an alternate use).

5.3.4 Disposal in Sanitary Landfill

Advantages

1. The sludge disposal problem is tranferred away from the water utility.
2. More environmentally acceptable than direct stream discharge, provided that the landfill has provisions for containing leachate.
3. Highly dewatered sludge (>40% TS) might help meet cover material requirements where imported cover is needed.

Disadvantages

1. Solid waste facility may not accept the waste or may place restrictions on it.
2. Dilute sludge (less than 20% TS) may create muddy landfilling conditions.
3. The need to mix 20-40% TS sludge with solid waste complicates landfill disposal operations.
4. Valuable resource (aluminum or alum) is permanently lost.
5. Potential for elevated aluminum levels and various heavy metals in landfill leachate.

5.3.5 Agricultural Land Disposal

Advantages

1. May improve soil structure and water retention.
2. Improves plant growth at limited application rates.

Disadvantages

1. Limited operating experience and potential unknown problems.
2. May adversely affect vegetation at excessive application rates.
3. Seasonal operation.
4. May only to suitable on certain types of soils.

5.4 RELATIVE COSTS

Cost comparisons cannot be presented without specific cases in mind. Therefore, the approach taken in this section is to present comparative cost information from the literature in a general fashion.

In Table 5-1, the relative order of capital and O&M costs for various options are presented. The table should be considered only as a rough ranking of options in terms of cost, from the least costly to the most costly.

TABLE 5-1

RELATIVE COSTS FOR WTP ALUM SLUDGE TREATMENT AND DISPOSAL (1)

OPTION		REFERENCE			
		Hutchison, *et al.*, 1973 (2)	Nielsen *et al.*, 1973 (3)	Westerhoff & Cornwell, 1978	Salotto *et al.*, 1973
- Lagoons	- Cap.	1			
	- O&M	1			
- Lagoons for Freezing	- Cap.	2			
	- O&M	2			
- Sewer	- Cap.	3			1
	- O&M	3			
- Vacuum Filter	- Cap.		1		
	- O&M		3		
- Scroll Centrifuge	- Cap.		2		
	- O&M		2		
- Basket Centrifuge	- Cap.		3		
	- O&M		4		
- Pressure Filter	- Cap.	4	4	2 (4)	
	- O&M	4	1	2	
- Alum Recovery	- Cap.	5		1 (4)	
	- O&M	5		1	
- Dewatering in General					2

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(1) Relative order of expense, from least cost (low numbers) to greater costs (higher numbers).

(2) Relative costs for 4.5 ML/d plant.

(3) Capital costs for dewatering machines only.

(4) For liquid ion exchange process.

To provide a general idea of the order-of-magnitude costs for dewatering alum sludge, reported cost figures were analyzed further. The reported figures were then adjusted to account for US dollar exchange rates, and inflation of construction and O&M costs. The following order-of-magnitude costs are all reported in terms of 1984 Canadian dollars (adjusted costs).

Adjusted O&M costs for the Hemphill Settled Solids Facility are approximately $80/tonne solids, including labour and chemicals, but excluding power. The adjusted capital cost for this pressure filter dewatering plant is in the order of $25,000,000 (Foster, 1975). In 1982, the plant dewatered approximately 5,400 tonnes of solids (see Appendix C).

O&M costs for four dewatering methods were presented by Nielson *et al* (1973):

	ADUSTED O&M COST
Pressure Filter	- $110/tonne solids
Scroll Centrifuge	- $160/tonne solids
Vacuum Filter	- $170/tonne solids
Basket Centrifuge	- $170+/tonne solids

The lower O&M costs for pressure filters were mainly due to lower costs associated with haulage and disposal of smaller quantities of more concentrated sludge.

Nielsen (1978) indicated that scroll centrifuges proved much more costly to operate than originally estimated. At the Sobrante plant in California, it was necessary to rebuild the rotors approximately once each year at a cost of about $20,000 (adjusted cost). The design solids loading for the two centrifuges was 8.6 tonnes/day total.

Westerhoff and Cornwell (1978) presented estimated costs for the liquid ion exchange process. Adjusted O&M costs were approximately $250 to $370/tonne solids, without credit for alum recovery. These costs were reduced by $180 to $700/tonne solids, after considering a credit for the recovered alum. The lower cost reduction applied to a hypothetical plant dewatering about 900 tonnes of solids per year from a 208 ML/d WTP with a 12 mg/L alum dosage. The higher cost reduction applied to a hypothetical plant dewatering about 2,650 tonnes of solids per year from a 189 ML/d WTP with a 140 mg/L alum dosage. It was also estimated that the capital costs for alum recovery were less than 15% of the costs for pressure filtration.

Hutchison et al. (1973) estimated annual costs (annual O&M plus yearly carrying charges for capital debt) for collecting, treating and disposing of all WTP waste discharges in Ontario. The adjusted annual cost exceeded $10,000,000 for 32,000 ML of wastewater containing 14,000 tonnes of solids.

6.0 MANAGEMENT OPTIONS APPLICABLE IN ALBERTA

6.1 GENERAL

All of the options for alum sludge treatment and disposal presented in Section 4.0 and 5.0 may have application in Alberta. The options require evaluation on a case by case basis, as each situation is unique.

There are some options which appear particularly attractive in Alberta. These options include:

- direct stream discharge;
- discharge to sanitary sewer;
- natural freeze-thaw conditioning and dewatering; and
- alum recovery with re-use of recovered alum for phosphorus removal at WWTPs.

These options are discussed further in Sections 6.2 to 6.5

6.2 DIRECT STREAM DISCHARGE

Direct stream discharge of alum sludge may continue to be a viable option in Alberta. This should depend to a large extent on the results of bioassay tests of alum sludge toxicity. These tests are recommended in Section 8.0.

Direct discharge may be particularly applicable where the receiving stream provides sufficient dilution to ensure that downstream effects are negligible.

6.3 DISCHARGE TO SANITARY SEWER

Discharge of alum sludge to a sanitary sewer would appear to be one of the simplest means of disposal. However, the discharge would have to be regulated to ensure that effects on the sewer and the WWTP are manageable. The effects of alum on sewage lagoons was not noted in the literature. If alum sludge is discharged to sewage lagoons, then the required frequency of sludge removal is expected to increase.

Sewer discharge of alum sludge appears particularly applicable for Alberta municipal WWTPs requiring phosphorus removal. Alum sludge has been shown to improve phosphorus removal, although not to the extent of fresh alum. Overall savings in phosphorus precipitation chemicals at these plants might more than offset the additional costs of handling greater sludge volumes.

6.4 NATURAL FREEZING

Natural freeze-thaw sludge conditioning and dewatering appears particularly applicable in Alberta because of the generally cold, prolonged winters. This method may not be applicable at larger water treatment plants because of the large land area requirement.

Land area availability, soil conditions, water table, and minimumm freezing degree-days are the main factors requiring consideration of this alternative. It might even be possible to operate a freeze-thaw system without annual sludge removal, making the alternative even more attractive because of the associated cost savings and possible ultimate recovery of the site for an alternate use (perhaps recreation).

6.5 ALUM RECOVERY

Where quantities of WTP alum sludge are large and WWTPs require phosphorus removal, use of recovered alum from alum sludge appears practical. Phosphorus removal is currently required at Calgary's WWTPs and may be undertaken at the Edmonton Regional WWTP, currently under construction. Use of recovered alum from WTPs could help manage WTP alum sludge disposal problems on the one hand, while solving a WWTP problem on the other.

The main advantage of using recovered alum at a WWTP rather than a WTP is that organics recycling, possible THM formation, metals recycling, etc. would not be of concern.

It might be more practical to recover alum from WWTP sludge rather than WTP sludge. However, WTP sludge would appear preferable because of lower potential adverse effects from organics recycling/accumulation.

It is envisioned that the process would consist of the following:

- flow equalization of WTP alum sludge, if required;
- thickening;
- acidulation with sulfuric acid;
- storage/haulage of thickener overflow from WTP to WWTP storage;
- neutralization of thickener underflow (sludge) with lime;
- settling or dewatering of reduced sludge volume; and
- ultimate disposal of reduced sludge volume.

7.0 REGULATORY REQUIREMENTS

Letters were sent by the consultant requesting information on WTP alum sludge regulations, etc. from various provinces in Canada and states in the USA. The responses are summarized in Sections 7.1 and 7.2

7.1 CANADA

Information was requested from nine of Canada's ten provinces (Alberta excluded). Responses were received from seven of the nine provinces. The information is summarized as follows:

Number of Provinces that:	
- Permit direct discharge	3*
- Disallow direct discharge	2
- No alum sludge for disposal	2
TOTAL	7

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* May not be permitted in some cases.

Both Saskatchewan and Ontario apparently do not permit direct discharge of alum sludge to a receiving stream.

Saskatchewan's Water Works Design Criteria (1968) state that, where sludge cannot be discharged to a sanitary sewer, settling facilities should be provided.

Information on alum sludge regulations for Ontario was obtained through Underwood McLellan Ltd.'s Ontario office. Under Ontario regulations, direct discharge to surface waters is only permitted for material removed from traveling screens treating water which has not been chlorinated. Discharge of alum sludge to sanitary sewers is the most common disposal method. Lagooning is considered practical only for small plants where land requirements are small.

7.2 UNITED STATES

Information was requested from 46 states regarding WTP alum sludge disposal. Responses were received from 20 of the states. The relatively poor response rate may have been due to incorrect government departments/ divisions receiving the request for information. The study schedule and budget did not permit follow-up with those states failing to respond. The information is summarized as follows:

Number of States that:	
- Permit direct discharge	3
- Disallow direct discharge	15
- No indication	2
TOTAL	20

Of the states disallowing direct discharge, five of these indicated that regulations came under the federal National Pollutant Discharge Elimination System (NPDES). These regulations usually allow the following limits for water treatment plants:

	30 d avg.	7 d avg.
Total suspended solids	20 mg/L	30 mg/L
Iron	1 mg/L	2 mg/L
Manganese	1 mg/L	2 mg/L
Aluminum	1 mg/L	2 mg/L

In some states (e.g. New Hampshire), alum sludge is regulated under solid waste regulations as ultimate disposal is mainly to sanitary landfills. (New Hampshire, 1983).

Some states also have stream water quality standards or objectives which must be considered in disposing of alum sludge or decant water from a settling pond. For example, the State of Maine (1983) limits the instream concentration of aluminum to a daily maximum of 0.50 mg/L and a monthly average of 0.10 mg/L for protection of aquatic organisms.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Pertinent conclusions and recommendations arising from this study are as follows:

Conclusions

1. The present practice of disposing alum sludge to receiving streams in Alberta may or may not be environmentally acceptable. Further assessment of the practice is required to determine if the practice should continue to be allowed.

2. There appears to be a lack of good scientific evidence of problems from disposing alum sludge to receiving streams. There have been numerous suspicions expressed about adverse effects, but these often have not been substantiated by factual information.

3. Possible adverse effects of alum sludge discharges include:

   - formation of sludge deposits in quiescent areas of streams;
   - smothering effects on benthic organisms;
   - toxic effects on aquatic organisms (high toxicity has been reported in bioassay tests);
   - periodic high oxygen demand if WTP sludge is discharged in large slugs, or if previously deposited sludge is periodically re-suspended due to increased stream velocity;
   - increase in aluminum concentrations of downstream water supplies; and
   - aesthetic problem where stream flow, stream turbidity, and/or sludge dilution are low.

4. Alum sludge is gelatinous and difficult to handle and dewater. Its gelatinous nature and poor dewaterability generally increase with raw water colour and decrease with raw water turbidity.

5. The minimum solids concentration of dewatered alum sludge preferred for landfilling, when the sludge is mixed with refuse, is about 20% total solids (TS) by weight. This gives the sludge the appearance of soft clay. However, much more dilute sludges have been landfilled, causing some difficulties because of the creation of muddy conditions. At about 40% TS, the sludge resembles stiff clay. As such, it does not require mixing with refuse and can be landfilled separately, or possibly used as a cover material.

6. Alum sludge exhibits a wide range of characteristics which depend on the raw water characteristics (turbidity, etc.) and other factors. Parameters may range as follows:

Total Solids:	0.1 - 4%
Suspended Solids:	75 - 99% of TS
Volatile Solids:	10 - 35% of TS
Biochemical Oxygen Demand:	30 - 2,000 mg/L
Chemical Oxygen Demand:	500 - 20,000 mg/L
pH:	5.5 - 7.5
Aluminum:	4 - 11% of TS
Iron:	6.5% of TS (one sample)
Manganese:	<0.005 - 5% of TS

Arsenic:	<0.04% of TS
Cadmium:	<0.005% of TS
Individual Heavy Metals:	<0.03% of TS
Total Kjeldahl Nitrogen:	0.7 - 1,200 mg/L as N
Phosphate:	0.3 - 200 mg/L as P
Total Plate Count:	30 - >300,000 per mL

7. The following appear to be viable options for handling, treatment and disposal of alum sludge:

   - discharge to receiving stream;
   - reduce alum sludge quantities by substituting some polymer for alum;
   - discharge at controlled rates to a sanitary sewer;
   - lagooning, with natural freeze-thaw dewatering;
   - thickening and dewatering followed by landfilling; and
   - land application.

   Another option involves the elimination of alum sludge through the use of alternate coagulants.

8. When dewatered alum sludge is disposed in a landfill, segregated disposal may have merit. It is estimated that as much as 500 tonnes of aluminum as Al with an estimated value exceeding $1 million, could be deposited in a segregated landfill area each year for a city of 500,000 people. The technology to re-mine this aluminum deposit economically may not be available today, but possibly could be developed in future.

9. Alum recovery by acidulation and re-use at a water treatment plant may not be a viable option because of concerns with respect to heavy metal and organics recycling.

10. Re-use of recovered alum at a wastewater treatment plant for phosphorus removal appears promising.

11. Alum recovery by liquid ion exchange has not been demonstrated at full scale. The process may not be suitable because of the apparent high complexity of operation and possibility of alum contamination with solvent. These aspects were not addressed in any of the reviewed references.

12. Land application of alum sludge at controlled rates can have beneficial effects on soils, for example: decreased slaking and dispersion, improved soil aggregation, increased water retention, and increased crop yield.

13. The costs of full scale alum sludge dewatering systems can be very expensive in terms of both capital and operation and maintenance (O & M). Capital costs may represent over 30% of water treatment plant capital costs. O & M costs may be in the order of $100 per tonne of dewatered solids.

14. It appears that two Canadian Provinces (Ontario and Saskatchewan) and the majority of USA states prohibit direct discharge of WTP alum sludge to streams.

Recommendations

The following are recommendations for consideration by Alberta Environment:

1. Alberta Environment should initiate baseline data acquisition on alum sludge discharges to determine the magnitude of the practice in Alberta. Data should include:

    - physical and chemical characteristics of alum sludge;
    - disposal method;
    - quantity disposed to receiving water;
    - discharge rates, duration, frequency, timing, etc.;
    - minimum dilution; and
    - impacts on receiving waters (in terms of calculated increases of parameters above background levels).

2. Bioassay testing should be undertaken on selected alum sludges. Initially, limited testing should be performed on sludges where there appear to be potential disposal problems. Ultimately, the testing could be extended to include sludges producing the greatest calculated increases of water quality parameters above background stream levels as identified in (1).

3. Laboratory, pilot scale, or other experimental studies of alum sludge treatment and disposal should be conducted for specific plants having potential adverse impacts, as identified in (1) and (2). Methods which appear worthy of examination initially include:

- disposal to sanitary sewer with evaluation of impacts on sewer system and wastewater treatment processes including lagoons;

- natural freeze-thaw conditioning and dewatering:

  - with annual removal of dewatered, dried solids for landfill disposal,

  - with successive annual applications, in-place accumulation of freeze-thawed sludge, and ultimate land re-use or mining of the dried sludge to recover aluminum;

- alum recovery by acidulation with re-use of the recovered alum for phosphorus removal at wastewater treatment facilities.

4. Alberta Environment should develop guidelines with respect to alum sludge disposal in Alberta. Interim guidelines may be formulated, based on the findings of this study. The guidelines should be revised, as required, and finalized upon completion of the work outlined in (1) - (3).

5. If alum sludge dewatering is practised, the feasibility and merits of sludge disposal in segregated areas of a landfill should be investigated. With segregated disposal, ultimately it might be feasible to re-mine the deposited sludge to recover aluminum or alum.

6. The feasibility of land application of WTP alum sludge should be investigated further. Contacts with Ontario Ministry of the Environment and the New Haven Agricultural Experimental Station, in Conneticut are suggested starting points in the investigation.

9.0 REFERENCES

Alberta Environment. 1982. *Alberta Water and Wastewater Facilities Survey.*

Alberta Environment. c. 1982. *Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands.* Standards and Approvals Div. and Earth Sciences Div.

Albrecht, A.E. 1972. "Disposal of alum sludges". *Jour. AWWA*, 64:1:46.

AWWA Research Foundation. 1969. "Disposal of wastes from water treatment plants - Part 2". *Jour. AWWA*, 61:11:619.

AWWA Committee. 1972. "Disposal of water-treatment-plant wastes". *Jour. AWWA*, 64:12:814.

AWWA Committee. 1978a. "Water treatment plant sludges - an update of the state of the art: Part 1". *Jour. AWWA*, 70:9:498.

AWWA Committee. 1978b. "Water treatment plant sludges - an update of the state of the art: Part 2". *Jour. AWWA*, 70:10:548.

AWWA. 1983. "Limits on aluminum studied by EPA, FDA." *Mainstream*, 27:12:2.

Bishop, S.L. and G.P. Fulton. 1968. "Lagooning and freezing for disposal of water plant sludge". *Public Works*, 99:6:94.

Bishop, S.L. 1978. "Alternate processes for treatment of water plant wastes". *Jour. AWWA*, 70:9:503.

Bugg, H.M., P.H. King and C.W. Randall. 1970. "Polyelectrolyte conditioning of alum sludges". *Jour. AWWA*, 62:12:792.

Calkins, R.J. and J.T. Novak. 1973. "Characterization of chemical sludges". *Jour. AWWA*, 65:6:423.

Connecticut, 1983. Personal communication with B. Curtis.

Cope, C.S. 1983. Personal communication with Superintendent, Hemphill Settled Solids Facility, Atlanta, Georgia.

Cornwell, D.A. 1979. "An overview of liquid ion exchange with emphasis on alum recovery". *Jour. AWWA*, 71:12:741.

Cornwell, D.A. and R.M. Lemunyon. 1980. "Feasibility studies on liquid ion exchange for alum recovery from water treatment plant sludges". *Jour. AWWA*, 72:01:64.

Cornwell, D.A., G.C. Cline, J.M. Przybla and D. Tippin. 1981. "Demonstration testing of alum recovery by liquid ion exchange". *Jour. AWWA*, 73:6:326.

Doe, P.W. 1968. "A report on the disposal of sludge from water treatment plants". *Jour. British Water Works Assoc.*, Nov. 1968:638.

Doe, P.W. 1983. Personal communication.

Everhart, W.H. and R.A. Freeman. 1973. *Effects of Chemical Variations in Aquatic Environments: Volume II Toxic Effects of Aqueous Aluminum to Rainbow Trout*, EPA-23-73-011b.

Farrel, J.B., J.E. Smith Jr., R.B. Dean, E. Grossman III and O.L. Grant. 1970. " Natural freezing for dewatering of aluminum hydroxide sludges". *Jour. AWWA*, 62:12:787.

Foster, W. S. 1975. "Get the water out of alum sludge". *Am. City and County*, 90:9:83.

Fulton, G.P. 1969. "Disposal of wastewater from water filtration plants". *Jour. AWWA*, 61:7:322.

Fulton, G.P. 1976a. "Water plant waste treatment: state of the art - Part One". *Public Works*, 107:1:40.

Fulton, G.P. 1976b. "Water plant waste treatment: state of the art - Part Two". *Public Works*, 107:2:57.

Fulton, G.P. 1983. Personal communication.

Fujita, H. 1967. "Tokyo's Asaka purification plant". *Water and Sewage Works*, 114:3:73.

Gates, C.D. and R.F. McDermott. 1968. "Characterizataion and conditioning of water treatment plant sludges". *Jour. AWWA*, 60:3:331.

Gates, W.E. and Associates, Inc. 1981. *A Study of Wastewater Discharges from Water Treatment Plants*. Report prepared for Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio 45202.

Gruninger, R.M. and G.P. Westerhoff. 1974. "Filter plant sludge disposal". *Envir. Science and Tech.*, 8:2:122.

Gruninger, R.M. 1975. "Disposal of waste alum sludge from water treatment plants". Jour. WPCF, 47:3:543.

GRW Engineers, Inc. 1983. An Evaluation of the Effects of Wastewater Discharges from the Paducah Water Treatment Plant on the Quality of the Ohio River. Report prepared for Paducah Water Works, Kentucky 42001.

Guiver, K. 1972. "Pollution control in rivers serving as sources for public water supply". Water Treatment and Examination, 21:3:187.

Hawkins, F.C., J.F. Judkins Jr. and J.M. Morgan. 1974. "Water-treatment sludge filtration studies". Jour. AWWA, 66:11:653.

Helliwell, S., G.E. Bately, T.M. Florence and B.G. Lumsden. 1983. "Speciation and toxicity of aluminum in a model fresh water". Environmental Technology Letters, 4:141.

Hsu, D.Y. and W.O. Pipes. 1973. Aluminum hydroxide effects on wastewater treatment processes". Jour. WPCF, 45:4:681.

Hsu, D.Y. 1976. "Alum sludge from water plant conditions sewage sludge". Water and Sewage Works, 123:3:62.

Hutchison, W.R., A.P. Galati and Z.K. Khan. 1973. Water Plant Waste Disposal in the Province of Ontario". Project No. 73-1-31. Ontario Ministry of Environment.

Inhoffer, W.R. and P.W. Doe. 1973. "Design of wash-water and alum sludge disposal facilities". Jour. AWWA, 65:6:404.

James, C.R. and C.R. O'Melia. 1982. "Considering sludge production in the selection of coagulants". Jour. AWWA, 74:3:148.

James Jr., W.C. 1983. Personal communication with Administrator, Chattahoochee Settled Solids Facility, Atlanta, Georgia.

Kentucky, 1983. Personal communication with W. B. Gatewood.

Kos, P. 1977. "Gravity thickening of water-treatment-plant sludges". Jour. AWWA, 69:5:272.

Krasauskas, J.W. 1969. "Review of sludge disposal practices". Jour. AWWA, 61:5:225.

Krasauskas, J.W. and L. Streicher. 1969. "Status report on plant operation". Jour. AWWA, 61:11:621.

Mahoney, P.F. and W.J. Duensing. 1972. "Precoat vacuum filtration and natural-freeze dewatering of alum sludge". Jour. AWWA, 64:10:665.

Maine, 1983. Personal communication with D.J. Albert.

Neubauer, W.K. 1968. "Waste alum sludge treatment". Jour. AWWA, 60:7:819.

New Hampshire, 1983. Personal communicaiton with C.F. Woodbury.

Nielsen, H.L., K.E. Carns and J.N. DeBoice. 1973. Jour. AWWA, 65:6:385.

Nielsen, H.L. 1977. "Alum sludge disposal - problems and success". Jour. AWWA, 69:6:335.

Nielsen, H.L. 1978. "Water treatment sludge disposal - how and where?" Jour. Envir. Eng. Div., ASCE, 8:561.

Novak, J.T. and D.C. Calkins. 1975. "Sludge dewatering and its physical properties". Jour. AWWA, 67:1:42.

Novak, J.T. and M. Langford. 1977. "The use of polymers for improving chemical sludge dewatering on sand beds". Jour. AWWA, 69:5:106.

Oklahoma, 1983. Personal communication with Q. Pham.

Olson, R.L. 1976. "Alum sludge drying with basic extractive treatment". Jour. AWWA, 68:6:321.

Rengasamy, P., J.M. Oades and T.W. Hancock. 1980. "Improvement of soil structure and plant growth by addition of alum sludge". Commun. in Soil Science and Plant Analysis, 11:6:533.

Robberts, J.M. and C.P. Roddy. 1960. "Recovery and reuse of alum sludge at Tampa". Jour. AWWA, 52:7:857.

Salotto, B.V., J.B. Farrell and R.B. Dean. 1973. "The effect of water-utility sludge on the activated sludge process". Jour. AWWA, 65:6:428.

South Carolina, 1983. Personal communication with D.A. Solley.

Stanley Associates Engineering Ltd. and IEC-Beak. 1983. Glenmore Water Treatment Plant Waste Discharge Impact Alleviation Report. Prepared for City of Calgary.

Tomono, K. 1977. "The art of water treatment in Japan". Jour. AWWA, 69:3:166.

West Virginia, 1983. Personal communication with R.M. Sovic.

Westerhoff, G.P. 1972. "Filter plant wastewater treatment". Public Works, 103:10:79.

Westerhoff, G.P. and M.P. Daly. 1974. "Water-treatment-plant wastes disposal - Part 2". Jour. AWWA, 66:6:379.

Westerhoff, G.P. and D.A. Cornwell. 1978. "A new approach to alum recovery". Jour. AWWA, 70:12:709.

Wilhelm, J.H. and C.E. Silverblatt. 1976. "Freeze treatment of alum sludge". Jour. AWWA, 68:6:312.

Wilson, T.E., R.E. Bizzarri, T. Burke, P.E. Langdon Jr. and C.M. Courson. 1975. "Upgrading primary treatment with chemicals and water treatment sludge". Jour. WPCF, 47:12:2820.

Young, E.F. 1968. "Water treatment plant sludge disposal practices in the United Kingdom". Jour. AWWA, 60:6:717.

APPENDIX A

TERMS OF REFERENCE

TERMS OF REFERENCE FOR A STUDY ON:

THE TREATMENT AND DISPOSAL OF WATER-TREATMENT-PLANT ALUM SLUDGES

The consultant, based on in-house expertise and experience, literature reviews, direct contact with appropriate individuals and/or private and/or public agencies, shall prepare a report which outlines:

1. the approximate quantities of alum sludge generated as a function of raw water characteristics when alum (aluminum sulfate) is the principal coagulant used to remove turbidity from a water supply;

2. the approximate physical, chemical and biological quality of water-treatment-plant alum sludges as a function of raw water quality e.g. colour and turbidity, including but not limited to the following parameters:

    a) % aluminum,

    b) % inert solids (dry wt. basis),

    c) % organic solids,

    d) bacteriology (total and fecal coliforms),

    e) BOD_5,

    f) metals, and

    g) toxicity;

3. the dewatering characteristics of water-treatment-plant alum sludges;

4. the methods/processes available to dewater water-treatment-plant alum sludges, including associated conditioning processes, and the advantages/disadvantages of each, including relative and/or order-of-magnitude cost;

5. the methods/processes available to recover alum from water-treatment-plant alum sludges and the advantages/disadvantages of each, including relative and/or order-of-magnitude cost;

6. ultimate disposal methods of water-treatment-plant alum sludges, including, but not limited to:

    i) discharge to sanitary sewers;

    ii) land filling;

iii) permanent lagoon storage; and

iv) discharge to water courses

and the advantages and disadvantages of each, including relative and/or order-of-magnitude costs;

7. the posssible physical, chemical and biological effects of disposing of water-treatment-plant alum sludges into surface waters including, but not limited to, the following possible effects:

   i) formation of sludge deposits;

   ii) formation of visible sludge plumes;

   iii) increases in soluble aluminium concentrations;

   iv) adverse impacts on benthic organisms and fish populations;

   and if possible the threshold levels at which these effects may occur;

8. the general applicability of the water-treatment-plant alum sludge conditioning/dewatering/recovery/disposal methods identified in 4., 5. and 6. above at water treatment plants in Alberta and the general factors affecting applicability (eg. plant size and location);

9. regulatory requirements and methods of handling alum sludge in other jurisdictions, where such information is readily available;

10. description of any relevant, existing alum sludge treatment/recovery/disposal operations, including costs, where such information is readily available; and

11. any other information the consultant considers relevant to the treatment and disposal of water-treatment-plant alum sludges.

The consultant shall provide 5 copies of a draft report for review and comment by Alberta Environment prior to proceeding with preparation of the final report. The draft and final report shall contain a table of contents, recommendations and conclusions and a list of references. All statements, technical information etc. in the text of the report shall be referenced as necessary. The consultant shall provide 30 copies of the final report.

APPENDIX B

CHARACTERISTICS OF ALUM SLUDGE

TABLE B-1

CHARACTERISTICS OF ALUM SLUDGE

Parameter or Constituent	Units	Value	Comments	Reference
Total Solids (TS)	wt. %	0.3-1.5	General range.	Albretch, 1972
		0.8	Milwaukee; contained some activated carbon	
		0.1-3.5	General range; sludge quantity generally $\leq$ 1% of raw water treated.	AWWA, 1978a
		$\leq$ 1	General value with sludge collection equipment	Bishop, 1978
		4.05	Moberly (clean lake water source); greater concentration expected with turbid water.	Calkins & Novak, 1973
		0.2-1.0	With sludge collection	Fulton, 1976a
		> 1.0	When raw water sediment is major factor.	
		$\leq$ 1.85	Manually cleaned tank, inplace measurement.	Gates & McDermott, 1968
		3.74-4.32	Manually cleaned tank; measurement after draining but before flushing.	
		1.0	Design value for Passaic (river water), New Jersey.	Inhoffer & Doe, 1973
		0.1-0.3	Upflow clarifiers, three plants, New York.	Gruninger & Westerhoff, 1974
		0.1-0.5	Hydraulic removal, Sturgeon Point, New York.	

Table B-1 (continued)

Parameter or Constituent	Units	Value	Comments	Reference
Total Solids	wt.%	0.5-3.0	General range.	Mahoney & Duensing, 1972
		0.43	Average for two plants in New York State.	Neubauer, 1968
		11.7 5	Glenmore W.T.P., Calgary; in-place solids concentration for manually cleaned tanks. Glenmore W.T.P. - diluted sludge concentration with flushing water during tank cleaning.	SAEL _et al._, 1983
Volatile Solids (VS)	% of Total Solids	20-35 41	General range. Milwaukee	Albretch, 1972
		22.9-37.4 20.3-29.6	In-place measurement. After cleaning; before flushing.	Gates & McDermott, 1968
		35 24	Average - Shoremont W.T.P., New York Average - Wolcott W.T.P., New York	Neubauer, 1968
		25 15	Summer-Sabrante W.T.P., San Francisco Winter-Sabrante W.T.P., San Francisco	Nielsen _et al._, 1973
Suspended Solids (SS)	% of Total Solids	75-90 96	General range. Milwaukee	Albretch, 1972
		75-99	General range.	Mahoney & Duensing, 1972
		84	Average for two plants in New York State	Neubauer, 1968

Table B-1 (continued)

Parameter or Constituent	Units	Value	Comments	Reference
Aluminum	As Indicated	21.8% of T.S. as $Al(OH)_3$	Passaic, New Jersey	Inhoffer & Doe, 1973
		40% of T.S.* 15% of T.S.*	Summer - Sabrante W.T.P. Winter - Sabrante W.T.P.	Nielsen *et al.*, 1973
pH	pH units	5-7 7.0	General range. Milwaukee	Albretch, 1972
		7.0	Average for two plants in New York State.	Neubauer, 1968
		7.6-7.7	Glenmore W.T.P. Calgary, Alberta	SAEL *et al.*, 1983
BOD	mg/L	30-100	General range.	Albretch, 1972
		36-77	Average for two plants in New York State.	Neubauer, 1968
COD	mg/L	500-10,000	General range.	Albretch, 1972
		500-1,000	Average for two plants in New York State.	Neubauer, 1968
		340	Glenmore W.T.P., Calgary, Alberta	SAEL *et al.*, 1983

* As hydrated aluminum oxide, 2 $[Al(OH)_3 \cdot 1.25\ H_2O]$.

Table B-1 (continued)

Parameter or Constituent	Units	Value	Comments	Reference
Other Characteristics	As Indicated			
- Iron		6.5% of T.S.**	Passaic, New Jersey	Inhoffer & Doe, 1973
- Manganese		2.4% of T.S.***	Passaic, New Jersey	Inhoffer & Doe, 1973
- Specific Gravity		1.17	At 20% T.S. concentration	Neubauer, 1968
		Approx. 1.5	At 100% T.S. concentration	Neubauer, 1968

** As $Fe(OH)_3$.

*** As MnO_2.

TABLE B-2

CHARACTERISTICS OF WTP SLUDGES FROM VARIOUS AREAS IN ONTARIO*

		LAKE ONTARIO & ST. LAWRENCE RIVER		ST. CLAIR RIVER - LAKE ERIE TO NIAGARA FALLS		LAKE HURON		OTTAWA RIVER		INLAND RIVERS	
		Sedimentation Basins (10)**	Clarifiers (0)	Sedimentation Basins (3)	Clarifiers (3)	Sedimentation Basins (1)	Clarifiers (1)	Sedimentation Basins (5)	Clarifiers (0)	Sedimentation Basins (2)	Clarifiers (1)
TS (g/L)	- Range	17-270	-	34-106	1.0-7.6	-	2.1	1.3-11.8	-	0.9	1.5-2.1
	- Median	91	-	64	3.4	-	-	6.2	-	-	-
	- N***	11	-	3	3	-	1	5	-	1	2
SS (g/L)	- Range	12-218	-	34-102	0.8-7.4	136	1.9	1.0-40	-	0.25-8.1	1.3-1.4
	- Median	79	-	62	3.4	-	-	10.2	-	-	-
	- N	13	-	3	5	1	1	7	-	2	2
VS (g/L)	- Range	2-37	-	5-11	0.25-1.1	-	0.4	0.45-5.7	-	0.27	0.6
	- Median	18	-	8	0.8	-	-	5.2	-	-	-
	- N	10	-	3	3	-	1	3	-	1	1
pH	- Range	6.7-8.1	-	6.9-7.0	7.0-7.5	7.4	6.9	5.7-6.8	-	6.7-7.6	7.2
	- Median	6.9	-	-	7.2	-	-	6.0	-	-	-
	- N	12	-	2	3	1	1	7	-	2	1
BOD (mg/L)	- Range	120-1,900	-	240-6,000	6.0-160	-	240	6-280	-	3.5-60	3-11
	- Median	900	-	3,500	17	-	-	8	-	-	-
	- N	13	-	3	5	-	1	6	-	2	2
COD (mg/L)	- Range	5,900-27,000	-	4,200-14,000	150-700	-	4,200	410-10,250	-	40-3,700	330-540
	- Median	12,000	-	9,200	580	-	-	2,600	-	-	-
	- N	9	-	3	5	-	1	7	-	2	2
TKN (mg/L as N)	- Range	0.7-1,200	-	170	5-26	6.5	170	6.9-600	-	2.5-14	10
	- Median	525	-	-	21	-	-	50	-	-	-
	- N	10	-	1	3	1	1	6	-	2	1
PO_4 (mg/L as P)	- Range	0.3-300	-	1.0-70	1.4-76.	15.7	1.0	1.0-44	-	1.3-125	1.2-5.2
	- Median	100	-	-	6.0	-	-	7.0	-	-	-
	- N	11	-	2	5	1	1	5	-	2	2

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* Reference: Hutchinson et al., 1973. The type of sludge appears to be alum sludge in each case.

** Numbers in brackets refer to number of water treatment plants for which data are reported.

*** Number of observations or tests.

TABLE B-3

METALS AND BACTERIA LEVELS FOR ALUM SLUDGES FROM ONTARIO WATER TREATMENT PLANTS*

	RANGE	MEDIAN	N
METALS (ug/g dry wt.)			
Aluminum (Al)	680 - 111,800	21,900	23
Arsenic (As)	<0.1 - 390	5	23
Lead (Pb)	1 - 151	59	23
Chromium (Cr)	<4 - 132	<45	17
Zinc (Zn)	16 - 260	78	19
Copper (Cu)	7.5 - 182	33	18
Mercury (Hg)	0.002 - 0.158	0.043	12
Cadium (Cd)	<2 - 48	<10	18
Nickel (Ni)	14 - 207	32	19
Manganese (Mn)	<45 - 48,300	350	19
BACTERIA (per mL)			
Total Plate Count	30 - >300,000	120,000	12

* Reference: Hutchinson *et al.*, 1973.

APPENDIX C

REPORTS ON SITE VISITS TO ALUM SLUDGE DEWATERING FACILITIES

REPORT ON SITE VISIT TO
CHATTAHOOCHEE SETTLED SOLIDS FACILITY
ALTANTA, GEORGIA

SEPTEMBER 14, 1983

Prepared by:

Underwood McLellan Ltd.
Consulting Engineers and Planners
17007 - 107 Avenue
EDMONTON, Alberta
T5S 1G3

INTRODUCTION

The Chattahoochee Settled Solids Facility in Atlanta, Georgia is an alum sludge dewatering plant constructed in 1972. The facility was visited on September 14, 1983 to gain supplemental information for the Alum Sludge Treatment and Dewatering Study currently being conducted by Underwood McLellan Ltd. for Alberta Environment.

CONTACTS

- Mr. Walter James, Superintendent, Chattahoochee Water Treatment Plant (initial contact).

- Mr. Claude Huff, Superintendent, Chattahoochee Settled Solids Facility (main contact).

WATER TREATMENT PLANT

- Not visited due to time constraints (only the settled solids facility was visited).

- Pertinent information, as conveyed by Mr. James:

  - Plant treats raw water from the Chattahoochee River.

  - Raw water quality varies widely, with turbidities sometimes exceeding 400 JTU.

  - Facilities include raw water intake; trash rack; prechlorination; alum coagulation, flocculation and sedimentation; lime for pH adjustment, chlorination.

  - 60 MGD (US) design capacity, with average operation at 30 to 40 MGD (US).

- Alum sludge is discharged to separate settled solids facility located adjacent to the water treatment plant.

SETTLED SOLIDS FACILITY

- Includes settled solids mixing tank, sludge feed tanks, filter precoat feed system, lime feed system, pressure filters (filter presses), reclaimed water tank, dewatered cake disposal, and other features (refer to Figure C-1).

- Estimated plant capacity is 40 tons per day (based on eight cycles per day and five tons of solids per cycle).

Settled Solids Mixing Tank

- Receives sludge (2 to 20% solids concentration) from the water treatment plant sedimentation basins.

- Rotating mechanism with air injection along moving mechanism mixes sludge. Air also helps control odours.

- Sludge is pumped to sludge feed tanks, as required.

Sludge Feed Tanks

- Four (4) 4000 US gallon tanks, approximate.

- Fill capacity is 3000 to 3200 US gallons.

- Batch operation.

- Air helps mix lime.

- Air pressure used to force sludge from feed tanks to filter presses.

Filter Precoat System (3)

- Three silos similar to lime silos, and feeders.

- Diatomaceous earth or peralite (peralite currently used).

- Applied to filters before each run.

- Reduces filter blinding, extends filter runs, assists in release of filter cake at completion of filter cycle.

Lime Feed System (3)

- Bagged hydrated lime used.

- Three lime silos and feeders.

- Approximately 6 to 10% lime is used; amount is based on weight of alum sludge solids in feed tank.

- Applied to feed tank.

- Try to raise pH of feed tank sludge to 12.3 to 12.4 for best filtration.

Filter Presses (2)

- Plate and frame type, 44 chambers, 110 ft.^{3}, total area 1813 ft.^{2}.

- 225 psi operating pressure.

- Filter cloth - polypropylene; requires replacement every 12 to 15 months.

- Filter cloth replacement takes 8 people two weeks to complete.

- They hope to double filter cloth life with nylon instead of polypropylene.

- Filtration cycle takes 30 to 60 minutes.

- High pressure water cleaning required approximately every 2 weeks.

- High pressure steam cleaning required approximately every 6 weeks.

- 8,000 to 10,000 tons of solids are processed per year.

- Cake solids range from 36 to 50% with 45% average.

- Drier cake obtainable when greater portion of sand and silt is in raw sludge (associated with higher river flows due to rain/runoff).

- Before filter cake can be discharged, the sludge from the pipe header in the filters is discharged to one of 2 core expansion tanks.

- Filtrate is normally returned to the inlet of the water treatment plant.

- Filtrate can also be discharged to the water pollution control plant.

- Filtrate quality - approximately 10 JTU.

- Each cycle can dewater 4.5 to 5.0 tons of solids.

- 6 cycles per 8 hour shift is typical.

- 14 cycles per 8 hour shift is best performance achieved to date.

- May only do 2 cycles on dry days when river water quality is good.

- Cycles not run until sedimentation basin solids are at least 2%.

Reclaimed Water Tank

- Receives filter backwash water.

- Mixing pumps and reclaimed water pumps.

- Water returned to water treatment plant.

Dewatered Cake Disposal

- Cake transported from lower floor by conveyor belt up to dump truck.

- Dump truck hauls dewatered cake to landfill.

- Cake used as cover material in landfill, according to C. Huff.

Other Features

- Compact design.

- Pneumatic valves have operated reliably.

- Boiler for winter building heating and summer dehumidification.

- Air compressors (2) for pressurizing feed tanks, etc.

- Air blower for water treatment plant filter air scour.

- Air dryer for instrument air.

- Motor Control Centre (MCC) for both plants.

Problems and Operator Comments

- Operator was quite happy with plant as there were very few operating problems.

- Feed tanks should be larger; 3 large tanks preferred to 4 small ones:

  - Can feed both filters simultaneously only when raw solids are heavy enough, otherwise volume is insufficient to feed both filters.

  - Changing from one feed tank to another can cause pressure fluctuation in filter with possible problems.

- Filters have lost pressure on occasion resulting in spraying of sludge all over.

- Filters periodically may require scraping to dislodge cake; this is caused by:

  - improper precoat, or
  - improper lime feed, or
  - deteriorated filter cloth

- Lots of dust (lime, etc.)

- Inadequate ventilation (hoping to improve this).

- Feed tank air venting is extremely noisy.

Staffing

- Plant started with three 8 hour shifts per day.

- Now operating with two 8 hour shifts per day.

- Total of 18 staff - 13 on day shift and 5 on evening shift.

- C. Huff felt that 16 staff would be adequate:

  - 4 Operators
  - 3 Supervisors
  - 4 Labourers
  - 1 Superintendent
  - 1 Secretary
  - 3 Truck Drivers

- Staff not normally required during weekends and night; solids are left in the sedimentation tanks.

- Sometimes necessary to bring in crew on weekend or 3 night shifts per week when it rains (dirty water and greater solids production for dewatering).

Capital Cost

- Settled solids facility cost approximately $3 million (U.S. funds); 1969 - 1972 construction.

Operation and Maintenance Cost

- $30,929.91 for month of June, 1983, including chemicals, supervision, labour and materials (see attached sheet for breakdown).

- Costs exclude electricity.

Miscellaneous

- C. Huff thought that alum sludge had been discharged at one time to the Water Pollution Control Plant. However, the plant apparently could not handle the large amounts of alum sludge.

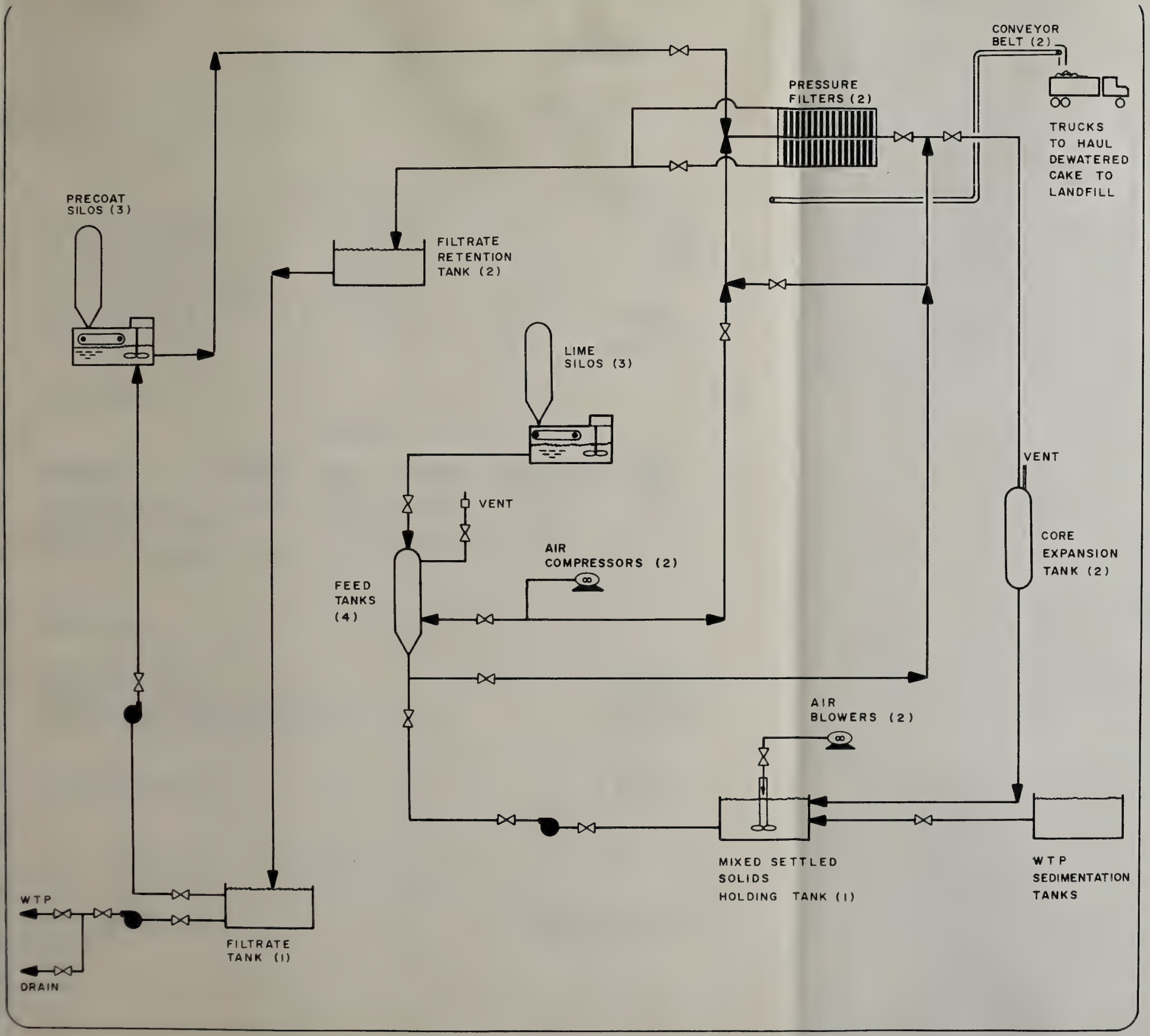
- Reference was made to the Cobb County dewatering facility operated by the Mirietta Water Authority. This is a smaller facility. Reported that a good cake is produced without the use of precoat for the filter presses.

- Pictures and slides were taken.

- Hemphill Settled Solids Facility, City of Atlanta, is a newer facility constructed in 1974 (approximately). See separate report on site visit.

UNDERWOOD McLELLAN LTD.

P. W. Given, P.Eng.
SENIOR ENVIRONMENTAL ENGINEER



Alberta
ENVIRONMENT

ALUM SLUDGE TREATMENT and DISPOSAL

NOTES

1. NUMBERS IN BRACKETS INDICATE THE QUANTITY OF EACH PROCESS UNIT.
2. ALL UNIT PROCESSES HOUSED IN FIVE STOREY BUILDING, EXCEPT WTP SEDIMENTATION TANKS.

SYMBOLS

⋈	VALVE
●	PUMP
⊥	MIXER
▭	CONVEYOR

CHATTAHOOCHEE
SETTLED SOLIDS
FACILITY
SIMPLIFIED SCHEMATIC

the uma group
Underwood McLellan Ltd.

Figure
C - 1

CITY OF ATLANTA

BUREAU OF WATER PRODUCTION BRANCH

TTAHOOCHEE SETTLED SOLIDS FACILITY

MONTHLY REPORT FOR:
June , 1983

. OPERATION DETAILS:

Total Solids Processed	Gals.	790,240
Average Conditioned/Raw Solids	%	8.6
Average Dryness of Cake	%	43.0
Total Solids Removed	Tons	548.6
Total Sludge Pumped to Plant	Gals.	
Total Water Not Reclaimed	Gals.	
Total Filtrate to W. P. Control Plt.	Gals.	266,444
Total Water Treated by W. T. Plant	MG	1,122.1
Total Reclaimed Water	Gals.	24,420,590

. CHEMICAL SUMMARY:

Chemicals	QUANTITY				
	Received (1)	Used (2)	On Hand (3)	Unit Cost (4)	Amount (2x4)
Hydrated Lime Lbs.	42,000	46,083	83,876	.03425	1,578.34
Perlite Filter Aid Lbs.					
Chlorine Lbs.					
Diatomaceous Earth Lbs.	None	7,025	15,485	.149	1,046.73

COST SUMMARY:

Cost of Chemicals	$ 2,625.07
Supervision & Labor	23,067.25
Operation & Maintenance (Material Cost)	5,237.59
Laboratory (Salaries, Chemicals, Materials, etc.)	- - - -
TOTAL OPERATIONAL COST	$ 30,929.91

DATE: 7-5-83

SUPERINTENDENT

REPORT ON SITE VISIT TO
HEMPHILL SETTLED SOLIDS FACILTY
ATLANTA, GEORGIA

SEPTEMBER 14, 1983

Prepared by:

Underwood McLellan Ltd.
Consulting Engineers and Planners
17007 - 107 Avenue
EDMONTON, Alberta
T5S 1G3

INTRODUCTION

The Hemphill Settled Solids Facility in Atlanta, Georgia is an alum sludge dewatering plant constructed in 1974. The facility was briefly visited on September 14, 1983 to gain supplemental information for the Alum Sludge Treatment and Dewatering Study currently being conducted by Underwood McLellan Ltd. for Alberta Environment.

CONTACTS

- Mr. Earl Jones (initial contact)

- Mr. Clyde S. Cope, Superintendent, Hemphill Settled Solids Facility

- Mr. A. W. Donaldson, Maintenance Supervisor

WATER TREATMENT PLANT

- The Hemphill Water Treatment Plant is a separate facility, not visited due to time constraints (only the Settled Solids Facility was visited).

- Pertinent information on the water treatment plant (WTP), as conveyed by Mr. Jones:

  - A raw water reservoir provides one day retention of raw water prior to treatment.

  - WTP design capacity is 110 to 115 MGD (U.S.) with average operation at 75 to 85 MGD (U.S.).

  - Same treatment process as for Chattahoochee WTP; however, raw sludge solids concentrations are lower (0.5 to 2.0%), because of raw water reservoir removal of sand and turbidity.

- Low sludge concentrations from sedimentation basins during dry weather conditions.

- Higher sludge concentrations during wet weather conditions.

SETTLED SOLIDS FACILITY

- Includes prechlorination contact chamber, raw water reservoir, clarifier thickeners, filter precoat feed system, lime feed system, sludge feed tanks, filter presses, dewatered cake disposal, and other features.

Prechlorination Contact Chamber

- Actually not a component of the settled solids facility.

- Constructed to provide prechlorination of raw water prior to raw water storage reservoir.

- Not in operation as chlorine residual cannot be maintained in the raw water.

Raw Water Reservoir

- One day retention of raw water from Chattahoochee River prior to WTP.

Clarifier Thickeners

- Total of 5 thickeners, 20 feet deep.

- 3 thickeners at 1.0 Mgal. (U.S.) capacity, receiving settled sludge from sedimentation basins, solids from core expanders, and local storm sewer drainage around the settled solids facility.

- 2 thickeners at 1.5 Mgal. (U.S.) capacity, receiving filter backwash water and local storm sewer drainage around the WTP.

- Sludge is thickened to 6 to 9% solids concentration.

- If solids become too thick (greater than 9%), then air can be bubbled in to mix the contents and thereby reduce the thickness of the sludge.

Filter Precoat System

- 3 silos/feeders.

- Diatomaceous earth used.

Lime Feed System

- 3 silos/feeders.

- Bagged, hydrated lime.

- Used for sludge conditioning (pH 12.3 to 12.4 for best results).

Sludge Feed Tanks

- Three 12,000 gal. (U.S.) tanks.

- One tank used at a time.

- Sludge feed to filter presses via ejector system.

Filter Presses (2)

- Passavant plate and frame type, 51 plates.

- Operating pressure greater than 200 psi.

- Filter cloth - polypropylene.

- During summer, sludge temperature is higher and pH is lower; requires more lime to raise pH to 12.3 - 12.4; sludge dewaters better with this greater lime dosage.

- Dewatering is not as effective at colder temperatures and higher pH during winter operation.

- Approximately 6,000 tons of sludge were processed last year.

- Cake is 30 to 35% solids.

- Maximum throughput - 13 filter runs per 8 hour shift.

Dewatered Cake Disposal

- Dump trucks receive cake 2 floors below filter presses.

- Conveyer system conveys cake laterally on floor between filter presses and dump trucks.

- Dump trucks can hold 2 process loads.

- Average of 2 to 3 truck loads per day hauled to sanitary landfill.

- C. Cope indicated that the dewatered sludge is not used as cover material in landfill; sludge is just buried with other wastes; sludge becomes slippery when wet.

Problems/Operator Comments

- Lime feed system plugs occasionally.

- Sludge core (from distribution header in filters) will not blow out at termination of a filter cycle if the solids concentration is greater than 9% (insufficient air pressure); requires manual blow out at greater air pressure.

- Polypropylene filter cloth tends to deteriorate around the stay bosses.

- Ejector system (rather than pumps) for transferring sludge is prone to high maintenance; leakage from gaskets is the main problem; 30 to 40 - 12" valves - gasket replacement is expensive.

- Costly to run air compressors for ejectors.

- Instrumentation is too elaborate according to Mr. Cope; also it is not the most modern by today's standards.

- Some difficulty in getting replacement parts for equipment. Problem is sometimes due to excessive time taken in bidding process.

- Filter precoat applied only from one end of filter; should be applied from both ends to get more even distribution (Note: Sludge is applied from both ends).

Staffing

- Total of 23 personnel for settled solids facility.

- Operate with one 8 hour shift per day, 5 days per week.

Capital Cost

- E. Jones thought capital cost was $4.5 million (U.S.) for 1974 completion.

Operating Data

- See appended sheets.

UNDERWOOD McLELLAN LTD.

P. W. Given, P.Eng.
SENIOR ENVIRONMENTAL ENGINEER

Form 48-D-447 Rev. 8/82

ATLANTA WATER WORKS
HEMPHILL SETTLED SOLIDS FACILITY
OPERATOR REPORT SHEET

Date Sept. 13 1983

Tot. avg.

Run Number			1	2	3	4	5	6								6	1
Filter Press Number			I	II	I	II	I	II									
Time	Start		8:37	9:34	10:41	11:50	12:46	1:38									
	End		9:29	10:36	11:45	12:49	1:33	2:35									
	Total Minutes		52	62	64	59	47	57								341	57
Specific Gravity			1.39	1.27	1.22	1.21	1.23	1.18								7.55	1.26
Feed Tanks % Solids	Tank No. 1				8.5			7.4									
	Tank No. 2		8.8			9.5										50.3	8.4%
	Tank No. 3			7.8			8.3										
Lime Added	Tank No. 1				500			500									
	Tank No. 2		500			500			500								
	Tank No. 3			500			500										
	Total		500	500	500	500	500	500	500							3500	500
pH	Tank No. 1				12.2			12.1									
	Tank No. 2		12.2			12.1											12.2
	Tank No. 3			12.2			12.1										
Volume	Tank 1	Initial			10,000			10,000									
		Final			5400			5400									
		Total			4600			4600									
	Tank 2	Initial	10,200			10,000											
		Final	6000			6400											
		Total	4200			3600											
	Tank 3	Initial		10,000			10,000										
		Final		5400			6000										
		Total		4600			4000										
	Total for Run		4200	4600	4600	3600	4000	4600								25600	4267
Precoat Added			66	66	66	66	66	66								396	66
Filter Pressure (Final)			200	200	200	200	200	200									
% Cake			34.1	30.0	34.3	35.0	37.8	29.3								200.5	33.41
Pounds			10,634	9716	9716	9257	9410	9027								57760	9627
Filtrate pH			11.9	12.1	12.1	12.1	12.0	12.1									12.1
Filtrate Turbidity			3.0	7.0	1.2	7.2	7.5	4.7									5.1 NTU
Filtrate Color			Clear	Clear	Clear	Clear	Cloudy	Cloudy									
Water Added			1000	1000	1000	1000	1000	1000									
Operator			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									

REMARKS:

CHEMICALS DUMPED

SHIFT	LIME	PRECOAT
12 M.N. - 8 A.M.	—	—
8 A.M. - 4 P.M.	47	0
4 P.M. - 12 M.N.	—	—
TOTAL	47	0

N.L.C. - B.N.C.
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